

CANADIAN JOURNAL OF SOIL SCIENCE

(formerly published as part of *Canadian Journal of Agricultural Science*)

VOLUME 37

AUGUST 1957

No. 2

TILLAGE PRACTICES IN RELATION TO CROP YIELDS, POWER REQUIREMENTS AND SOIL PROPERTIES

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[Received for publication February 21, 1956]

ABSTRACT

Tillage experiments were conducted on Burford loam and Lockport clay loam. Different implements and combinations of implements were used to accomplish nine methods of tillage. The mouldboard plough was used as a standard treatment and compared with other treatments using a plough equipped with sub-bases, a disk plough, a one-way disk, a field cultivator, and rotary tillage. Crop yields, power requirements, and the effect on soil physical properties were studied.

On Burford loam, with a 5-year rotation of corn, oats, and hay for three years, the yield of oats was significantly better when the fall tillage included mouldboard ploughing. No tillage treatment resulted in significant differences in the yields of corn as silage, and of hay. On Lockport clay loam, the crop yields from a rotation of corn, oats, hay, fall wheat, and red clover, were not significantly affected by tillage treatment.

Tillage treatments did not produce significant differences in soil aggregation, bulk density or aeration porosity in any year of the experiment. Significant differences were from year to year when the mean values of all treatments were compared.

The power required to accomplish the tillage treatments was measured.

INTRODUCTION

Tillage is a necessary farm operation which has received little attention from research workers in Ontario particularly in relation to crop yields, power requirements, and the effects on soil physical properties. In certain instances low yields or impaired soil physical conditions have been attributed to improper tillage. Opinions vary as to the depth and amount of tillage a soil requires to produce an environment suitable for the optimum growth of crops.

Field experiments were designed to evaluate several tillage treatments on two soils. The mouldboard plough was accepted as a standard tillage operation to be compared with deeper tillage using a plough equipped with sub-bases, a minimum amount of tillage through the use of disks, disk plough and field cultivator, and rotary tillage that mixed the crop residues

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throughout the tilled layer. In evaluating a tillage method three criteria were used: (1) crop yields; (2) power requirements in terms of horsepower-hours per acre; and (3) effects on aeration porosity, bulk density, and aggregation of the soils.

MATERIALS AND METHODS

The area of Burford loam was level and well drained, being underlain by coarse gravel. The surface soil was stone-free. The Lockport clay loam soil presented various problems in the proper timing of the tillage operations. The soil is handicapped by slow internal drainage; furrows are required to remove the surface water. The area was level and stone-free.

A 5-year rotation of corn, oats, and three years of alfalfa-brome hay was followed on the Burford soil with corn (silage), oats, and hay being used as index crops. On the Lockport soil the rotation was corn, oats, two years of alfalfa-brome hay, fall wheat, and red clover. The index crops were corn (silage), oats, fall wheat, and the alfalfa-brome hay. At both experimental areas, each crop of the rotation was grown each year.

Nine basic tillage treatments were achieved by using various implements or combinations of implements. The machines used and the depths of operation were:

1. Mouldboard plough—6 inches
2. One-way disk—3 inches plus the disk plough—6 inches
3. One-way disk—3 inches plus mouldboard plough—6 inches
4. Sub-base plough, with main base at 6 inches and the sub-base, an additional 4 inches
5. Disk plough—6 inches
6. One-way disk—3 and 5 inches, in two operations
7. Rotary tiller—3 and 5 inches, in two operations⁺
8. Mounted stiff-tooth cultivator—6 inches
9. Rotovator—5 inches⁺⁺

⁺ PTO driven

⁺⁺ Machine using a rotary spading principle, PTO driven, and equipped with L-shaped tines.

In preparing the plots for corn and oats, the basic tillage was done in the fall. Supplemental fitting in the spring consisted of disk harrowing and a final smoothing with harrows prior to seeding. All plots received the same amount of tillage in the spring. The fall wheat plots received the basic tillage after the hay was removed and as soon as soil moisture conditions permitted. The supplemental fitting was done just prior to seeding in early September.

The experimental area was comprised of five or six ranges depending on the rotation, which meant that for any one year only one crop was found in a range. Each range was divided into plots corresponding to the number of tillage treatments. Each treatment was randomized and replicated three times. On the Burford soil an individual plot measured 72 ft. \times 30 ft.;

on the Lockport soil, each plot was 86 ft. \times 20 ft. Twenty-five-foot headlands separated each range and provided adequate space for turning implements or for getting them into operation before entering the plot area itself.

Grain and corn were planted at right-angles to the direction of the basic tillage. Fertilizer was applied at recommended rates for each crop. No manure was used. Grain and silage yields were calculated from duplicate rod-row samples. The yield of grain was expressed as bushels per acre, 3 per cent moisture; the silage yields as tons per acre at 14 per cent moisture. Hay samples were obtained by cutting duplicate swaths, 2.5 ft. \times 30 ft. The yields were reported as tons of hay per acre at 14 per cent moisture.

The power, expressed as horsepower-hours per acre (h.p.-hr./ac.) required to operate the tillage implements, was calculated, using the data from a vacuum gauge recorder attached to the tractor manifold. The tractor had been rated against a dynamometer and a calibration chart of horsepower against the manifold reading was prepared. Two readings in each gear were obtained for each plot.

Soil samples were taken in August during a period when the soil moisture conditions were favourable for sampling. Samples were obtained from plots in corn, third-year hay on the Burford soil, and the second-year hay on the Lockport soil.

Core samples, 3 in., \times 3 in., were taken from the 2- to 5-inch depth. Four cores were secured from each corn plot and three from each of the hay plots. The cores were taken to the laboratory, saturated immediately, and drained under a tension of 40 cm. of water (1). The bulk density and aeration porosity were determined for each core. The bulk density was expressed as the oven-dry weight of a unit volume of soil. The aeration porosity was calculated from the volume of water removed from the core at the 40 cm. tension and expressed as a percentage of the total volume of the core.

Four samples from each plot were combined for aggregate analysis. The composite sample was worked gently through a half-inch screen, reduced in size by quartering, and air-dried before storing. The size-distribution of water-stable aggregates was determined in duplicate by the Yoder method (2), with the following modifications: a 50-gm. sample was mixed with 400 ml. of water by rotating 30 times in an end-over-end shaker. The results from the aggregate analysis were expressed as the percentage of the soil sample remaining as water-stable aggregates greater than 0.25 mm. in diameter.

RESULTS AND DISCUSSION

Crop Yields on Burford Loam

The yields of corn (silage), oats, and hay following various tillage treatments are given in Table I.

TABLE 1.—THE YIELDS OF SEVERAL CROPS USING VARIOUS TILLAGE TREATMENTS ON BURFORD LOAM

Tillage treatment	Yields per acre Average 1950-53 inclusive		
	Corn silage, tons	Oats, bu.	Hay, tons ⁺
1. Mouldboard plough	3.4	48.8	1.6
2. One-way disk + disk plough	3.0	43.8	1.6
3. One-way disk + mouldboard	3.1	48.0	1.6
4. Sub-base plough	3.4	45.5	1.5
5. Disk plough	3.3	46.6	1.5
6. One-way disk	3.8	42.9	1.6
7. Rotary tiller	2.8	42.0	1.8
8. Cultivator	3.0	39.9	1.8
L.S.D. (P = 0.05)	N.S.	4.1	N.S.
L.S.D. (P = 0.01)	N.S.	5.7	N.S.

⁺ Average of the 3 years of hay in the rotation.

The yields of corn from the plots where the one-way disk was used were higher than those of all other treatments but the differences were not significant (Table 1). Weeds were more common on the plots that received a form of mulch tillage such as resulted from the use of the cultivator, one-way disk, and rotary tillage. Those plots that were ploughed with the mouldboard plough presented the least problem in weed control.

The use of the mouldboard plough alone and in combination with the after-harvest disking of corn stubble, (Treatment 3), resulted in the highest yields of oats. These yields were significantly better than those following such tillage treatments as the cultivator, rotary tiller, one-way disk, and the one-way disk plus disk plough.

No significant differences were noted in the yields of hay.

Crop Yields on Lockport Clay Loam

The yields of corn (silage), wheat, oats, and hay following various tillage treatments are found in Table 2.

TABLE 2.—THE YIELDS OF SEVERAL CROPS USING VARIOUS TILLAGE TREATMENTS ON LOCKPORT CLAY LOAM

Tillage treatment	Yields, per acre Average 1950-54 inclusive			
	Corn silage, tons	Wheat, bu.	Oats, bu.	Hay, tons
1. Mouldboard plough	2.0	35.0	47.5	1.6
3. One-way disk + mouldboard	2.0	32.3	46.7	1.6
5. Disk plough	2.0	34.2	41.6	1.5
6. One-way disk	2.0	32.2	44.4	1.8
7. Rotary tiller	2.0	34.8	45.1	1.6
9. Rotovator	2.1	37.5	44.0	1.7
L.S.D. (P = 0.05)	N.S.	N.S.	N.S.	N.S.

The data in Table 2 show that none of the tillage treatments had a significant effect on crop yields.

Power Consumption

The comparison of the horsepower hours per acre required by the different tillage practices is shown in Figure 1.

With the exception of the one-way disk on Burford loam and the mouldboard plough on the clay loam, power consumption was greater on sod land. The one-way disk required the least power on both soil types, except on the corn stubble where penetration was deeper on the loam soil than on the clay soil resulting in an increased power requirement. However, where other similar practices (Treatments 3 and 5) were used on the two soil types, comparable power was required. The rotary tiller required approximately two to three times the horsepower of any of the other tillage implements on the Lockport soil.

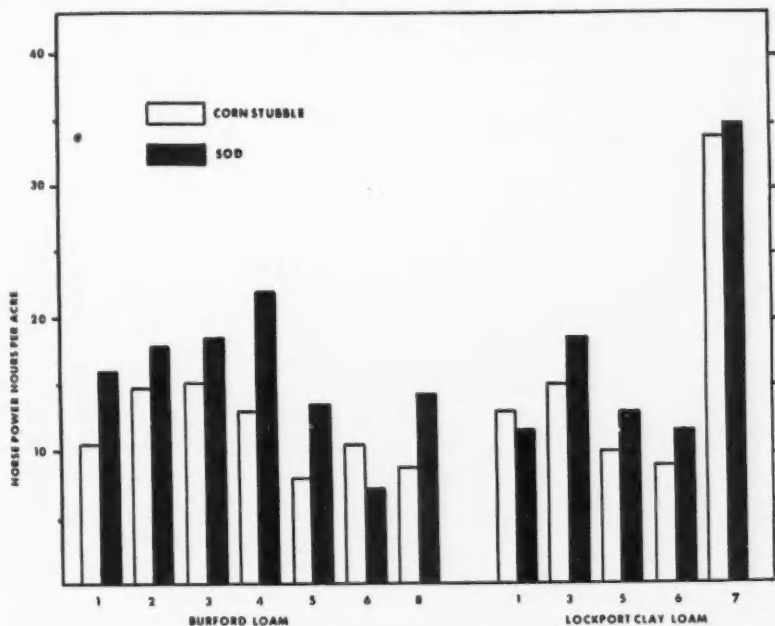


FIGURE 1. Power consumption of tillage machines.

A comparison of the power requirements (horsepower-hours per acre) for several tillage treatments on the Burford and Lockport soils after corn stubble, and sod. Tractor was operated in second gear. (The power requirements for the rotary tiller on the Burford and the rotovator on the Lockport were not obtained).

Burford

1. Mouldboard plough
2. One-way disk & disk plough
3. One-way disk & mouldboard
4. Sub-base plough
5. Disk plough
6. One-way disk
8. Cultivator

Lockport

1. Mouldboard plough
3. One-way disk & mouldboard
5. Disk plough
6. One-way disk
7. Rotary tiller

TABLE 3.—PHYSICAL PROPERTIES OF BURFORD LOAM AND LOCKPORT CLAY LOAM FOLLOWING VARIOUS TILLAGE TREATMENTS*
(Mean values for all replications for all years)

Tillage treatment	Aeration porosity, per cent				Bulk density, gm./cm. ³				Aggregation, per cent 70.25 mm.			
	Burford		Lockport		Burford		Lockport		Burford		Lockport	
	Hay	Corn	Hay	Corn	Hay	Corn	Hay	Corn	Hay	Corn	Hay	Corn
1. Mouldboard plough	8.5	11.0	8.7	14.0	1.35	1.24	1.41	1.30	23.90	13.6	25.18	21.6
2. One-way disk + disk plough	8.4	13.9			1.36	1.20			22.60	13.2		
3. One-way disk + mouldboard	8.7	14.0	8.4	15.8	1.36	1.21	1.44	1.31	22.75	14.1	24.88	19.0
4. Sub-base plough	7.1	13.5			1.36	1.21			23.73	14.5		
5. Disk plough	7.7	13.8	8.2	13.7	1.34	1.19	1.43	1.33	24.23	13.6	27.62	20.0
6. One-way disk	8.2	13.0	8.5	15.1	1.37	1.22	1.41	1.33	23.47	15.3	26.31	23.6
7. Rotary tiller	8.6	13.6	8.5	13.4	1.33	1.20	1.40	1.31	22.78	14.7	24.51	23.3
8. Cultivator	7.6	13.1			1.34	1.20			22.15	14.6		
9. Rotovator			7.9	13.7			1.44	1.31			25.87	24.0
L.S.D. (P = .05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Soil sample from 2- to 5-inch depth.

For both soil types, the practice of using two tillage implements (Treatment 3), where each machine did a partial job of tilling resulted in a greater total power consumption than that required when either machine did the complete job (Treatments 1 and 6). From the yields obtained, this increased power consumption was not warranted.

When the horsepower required per foot of cut of an implement was determined, that in second gear was considerably higher than that in first gear; but the increased speed of second gear compensated for the increased horsepower resulting in comparable horsepower hours per acre.

Soil Properties

The data from the physical analysis of the soil samples are presented in Table 3.

No tillage treatment brought about significant differences between any of the physical measurements as shown in Table 3. With the exception of aggregation, the soil properties under study were better under corn than under hay. It seems reasonable to assume that the higher aeration porosity and the lower bulk density under corn were directly related to inter-row cultivation as the improvements did not last through the balance of the rotation to the hay crop. The values of the various physical characteristics of the Lockport clay loam were greater than the values for the Burford loam.

When the mean values for all tillage treatments of the various physical properties after hay were examined, significant trends were noted during the course of the project (Table 4). For both soils, the aeration porosity was greatest in 1952 and decreased significantly each year thereafter. This decrease could not be attributed to any particular treatment; all treatments appeared to have caused a decrease in aeration porosity. In the Burford soil, the bulk density values were lowered each year but no change occurred on the Lockport soil. The values for soil aggregation increased on the Burford soil and this may account for the lower bulk density values; on the Lockport soil, aggregation reached a lower level as the bulk density values remained unchanged.

TABLE 4.—MEAN VALUES OF PHYSICAL PROPERTIES OF BURFORD LOAM AND LOCKPORT CLAY LOAM FOR ALL TILLAGE TREATMENTS AFTER HAY

Physical property and soil type	Years				L.S.D. (P = 0.01)
	1951	1952	1953	1954	
Aeration porosity					
Burford loam	7.4	9.6	7.4		1.0
Lockport clay loam	9.1	10.1	7.9	6.3	1.1
Bulk density					
Burford loam	1.39	1.36	1.31		0.03
Lockport clay loam	1.42	1.41	1.42	1.43	N.S.
Aggregation					
Burford loam		21.85	24.55		1.46
Lockport clay loam		28.31	24.42	24.45	1.74

While the values of the soil physical properties changed from year to year under hay, the changes could not be related to significant yield differences in the hay.

CONCLUSIONS

The data presented do not indicate that any of the tillage treatments were superior to the conventional mouldboard plough. From the yield results obtained with the one-way disk, which had the lowest power requirement, it could be argued that an unnecessary amount of power was expended in tillage. However, better weed control was obtained with the mouldboard plough.

The results of the studies on the soil physical properties indicated that the greater aeration porosity after corn could be attributed to inter-row cultivation and was only temporary. Soil aggregation values were greater after hay than after corn. All tillage treatments induced significant decreases in aeration porosity during the latter two years of the project. This observation suggested that the project may have been terminated prematurely.

This project was not designed to measure the effects on crop yields or soil properties of different crop rotations. The type of rotation selected for each soil type was believed to be "soil-building". Where a rotation, including two or three years of hay, is followed, the effects from tillage treatments may be masked by the crop and rotation effects.

ACKNOWLEDGEMENTS

The authors are indebted to several assistants who, during the course of the experiment, conducted the laboratory work. Appreciation is extended to William Breckon on whose farm the Lockport soil was located.

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THE GROWTH AND MINERAL CONTENT OF FLUE-CURED TOBACCO AS INFLUENCED BY REACTION OF NUTRIENT SOLUTIONS WITH IONIC FORMS OF NITROGEN¹

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[Received for publication November 26, 1956]

ABSTRACT

Studies with flue-cured tobacco in sand culture showed that the optimum reaction of the culture medium varied with the ionic forms of nitrogen supplied. Nitrate nitrogen was assimilated most efficiently at pH 5. When both nitrate and ammonium nitrogen were supplied, pH 8 was optimum. Ammonium nitrogen was assimilated by the plant as readily as nitrate when the reaction of the culture medium was favourable.

The accumulation of all the major nutrient elements in the leaf tissue was influenced by the reaction of the culture medium. The ash content of the leaves was highest over the range of pH values 4 to 6, inclusive.

INTRODUCTION

It has been recognized for some time that the hydrogen-ion concentration of the culture medium may have both direct and indirect effects on plant growth and the influence of this factor on the growth of plants in solution culture has been studied with varying results. Curtis and Clark (2) stated that the influence of hydrogen-ion concentration on the absorption and accumulation of salts has not been definitely established but data from several sources indicate that the cations are accumulated to a greater extent from alkaline solutions and anions, from acid solutions. Steinberg (7) found that initial pH values of 4.6 and 7.0 in water culture were without major effects on the absorption of magnesium and calcium by oriental Xanthi tobacco.

Data from several sources indicate that the H-ion concentration of the nutrient solutions in which plants are grown influences the absorption and assimilation of nitrate and ammonium nitrogen. Theron (8) reported that an acid medium favoured nitrate assimilation. Tiedjens and Robbins (9) found that the tomato plant assimilated nitrate best at pH 4 to 5 and ammonium nitrogen best at pH 7 or above.

The writer previously reported (4) that burley tobacco grown in sand culture gave a differential response to two ionic forms of nitrogen. A concentration of one-third ammonium and two-thirds nitrate nitrogen in the nutrient solution did not have a significant effect on yield as compared to all-nitrate nitrogen, but a progressive increase in the proportion of ammonium nitrogen resulted in a progressive decrease in yield. It was also found that the content of inorganic nutrients in the plant was influenced by the relative proportion of the two forms of nitrogen in the nutrient supply. In this investigation, the reaction of the nutrient solutions was unadjusted. However, if the plants were grown on a series of nutrient solutions in which both the concentration and ionic forms of nitrogen were constant but in which the H-ion concentration was varied, the effect of the reaction of the culture medium on the ability of the plant to absorb

¹ Contribution from the Tobacco Division, Experimental Farms Service.

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and assimilate specific ionic forms of nitrogen, as well as other nutrients, should become apparent. A study of two series of tobacco plants grown under these conditions is the subject of this paper.

MATERIALS AND METHODS

White Mammoth, a variety of flue-cured tobacco, was used in the two experiments. The seedlings were grown in washed ground sandstone in 3-inch pots for eight weeks and supplied with an optimum nutrient solution, previously developed (3). This solution was compounded from the following reagent-grade salts: $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, KH_2PO_4 , and $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. It contained the major nutrient elements Ca, Mg, K, N, S, and P at concentrations of 240, 45, 195, 168, 60, and 155 p.p.m., respectively. The minor elements B, Mu, Cu, and Zn were each added to the solution at the rate of 0.5 p.p.m., and Fe was added at the rate of 3 p.p.m.

The seedlings were transplanted to 3-gal. glazed, self-draining crocks, each containing 40 lb. of washed ground sandstone. One plant was grown per crock and was supplied with one litre of nutrient solution per day by the constant-flow drip method. Six plants were used in each treatment. Two weeks after topping, the plants were harvested and fresh weights were recorded for top leaves and bottom leaves. Separate samples of top leaves and bottom leaves, cut into small pieces and well mixed, were weighed out for dry-weight determinations and dried in an oven at 70° C. The methods used in the chemical analyses were the official methods of the A. O. A. C. (1) with one exception—total nitrogen was determined by the method of Pucher *et al.* (6).

In Experiment 1, all plants were supplied with complete nutrient solutions over the reaction range of pH 3 to 9, inclusive, in gradations of 1 pH unit. The seven nutrient solutions consisted of that used for the seedlings with the pH values adjusted by the addition of the required amount of either H_2SO_4 or NaOH. Therefore, the seven solutions were identical in nutrient content with the following exceptions: the use of H_2SO_4 added 21, 12, and 8 p.p.m. S to the pH 3, 4, and 5 solutions, respectively; and the use of NaOH added 0.1, 0.8, 1.3, and 1.8 p.p.m. Na to the pH 6, 7, 8, and 9 solutions, respectively. All the nitrogen in these treatments was in the NO_3^- form.

In Experiment 2, eight nutrient solutions were tested over the pH range 2 to 9, inclusive. The nitrogen in these solutions was in two ionic forms as follows: 28 p.p.m. NH_4^+ nitrogen and 140 p.p.m. NO_3^- nitrogen, making a total of 168 p.p.m. nitrogen. The concentrations of Ca, K, Mg, and S were 100, 136, 45, and 60 p.p.m., respectively. The concentration of P was reduced to 2 p.p.m. to prevent precipitation of this element. The minor elements were supplied as in the solution for the seedlings. Again, H_2SO_4 and NaOH were used to adjust the reaction of the nutrient solutions. Therefore, all eight solutions were identical in nutrient content, except that the use of H_2SO_4 added 150, 25, 13, 9.6, and 6 p.p.m. S to the pH 2, 3, 4, 5, and 6 solutions, respectively; and the use of NaOH added 0.2, and 0.8 p.p.m. Na to the pH 8 and 9 solutions.

RESULTS

The yield data and the chemical analytical results for Experiment 1 are presented in Table I.

The acid region of the reaction range was more favourable for growth than the alkaline region and the H-ion concentration of the nutrient solutions had a significant effect on dry-weight yield. The yield at pH 5 was significantly higher than at all other cultures except pH 4.

In the alkaline cultures, the precipitation of nutrient ions was of sufficient intensity to change the chemical composition of the nutrient solutions. This condition resulted in an indirect effect of the reaction of the nutrient solutions on growth. The leaves in these cultures were narrow, indicating a deficiency of phosphorus. Also, the phosphorus content of both top and bottom leaves was significantly lower in the neutral and the alkaline regions of the pH range than in the acid region. This indicated that the availability of phosphorus to the plant was reduced by increasing pH values above 6. It was determined by chemical analysis that the precipitate collected from the alkaline solutions contained 28.7 per cent Ca^{++} and 51.1 per cent PO_4^{3-} on an air-dried basis.

The data show that the accumulation of all the major nutrient elements in the leaf tissue was influenced by the reaction of the culture medium.

Table 2 presents the results of Experiment 2, showing the response of the plant to variations in the H-ion concentration of the culture medium when nitrogen was supplied in both NO_3^- and NH_4^+ forms as compared to all- NO_3^- nitrogen in Experiment 1. It will be noted that the yield at pH 8 was significantly higher than at all other treatments. The pH 3 plants were stunted and the pH 2 plants died soon after the treatments were initiated. The plants at pH 4 to 9 had narrow leaves, indicative of mild phosphorus deficiency which is attributable to the low concentration at which this element was supplied to preclude its precipitation in the alkaline solutions as occurred in Experiment 1. The variation in reaction had little effect on the concentration of phosphorus in the leaves but it did have an effect on the leaf content of the other major nutrient elements and total ash.

DISCUSSION AND CONCLUSIONS

Consideration should be given to the possible influence on growth of variations in the supply of S and Na, added as H_2SO_4 and NaOH , respectively, to certain nutrient solutions. In Experiment 2, the plants died in the pH 2 solution which contained 210 p.p.m. S, including 150 p.p.m. added as H_2SO_4 . However, it is indicated that the high degree of acidity, not the S, was the lethal factor since tobacco plants supplied with 360 p.p.m. S grew to maturity in studies previously reported (3). These studies showed that the plant has a wide tolerance of S. It is thus indicated that the amounts of S added as H_2SO_4 in other cultures in Experiment 2, as well as in certain cultures in Experiment 1, were too small to have a significant influence on the growth and composition of the plants. Also, the limited effect of Na in a previous experiment (5) indicates that the small amounts of this element supplied to the plants in the present studies probably did not have a significant effect on growth and composition.

It is evident that the H-ion concentration of the culture media in both experiments had a significant effect on the growth of tobacco. However, the optimum pH value for growth varied with the ionic forms of nitrogen supplied. NO_3^- nitrogen was utilized in growth most effectively from an acid medium, the optimum pH value being 5, with a favourable reaction range of pH 4 to 6, inclusive. When part of the nitrogen was supplied as NH_4^+ , alkalinity favoured assimilation of nitrogen, the optimum pH value being 8, with a favourable reaction range of pH 7 to 9, inclusive. The ash content of the leaves was generally highest at moderate acidity and, with few exceptions, both high acidity and high alkalinity depressed the accumulation of individual mineral nutrients in the leaf tissue in varying degrees.

The data show that ammonium nitrogen was assimilated by tobacco as readily as nitrate nitrogen provided the pH of the culture solution was in the range 7 to 9. However, in moderately acid solutions, the ammonium nitrogen was absorbed less readily than the nitrate nitrogen.

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RELATIONSHIP OF NITRATE ACCUMULATION TO YIELD RESPONSE OF WHEAT IN SOME SASKATCHEWAN SOILS¹

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[Received for publication October 6, 1956]

ABSTRACT

The capacity of Saskatchewan soils to accumulate nitrate, as determined by a laboratory procedure, was investigated as a method for evaluating the response of wheat to nitrogenous fertilizers. The correlation coefficient between the field yield ratios (which are a measure of the response to nitrogen) and nitrate accumulation for 31 stubble fields was 0.846** and for 30 fallow soils was 0.830**. Greenhouse experiments with soil samples from 31 stubble fields showed a high correlation (0.874**) between nitrate accumulation and nitrogen uptake by wheat plants during a 30-day growth period.

It is considered that a significant increase from the application of nitrogenous fertilizers can be expected when the nitrate accumulation value is below 50 p.p.m. N in soil from stubble fields or 40 p.p.m. N in fallowed soils.

The use of fertilizers on cereal crops in Saskatchewan has increased gradually since 1931 when phosphatic fertilizers were introduced. Recently, interest has developed in the use of nitrogenous fertilizers on fields cropped the previous year. This has emphasized the need for a laboratory method of predicting response of cereal crops to nitrogen. Previous studies at this laboratory (5) have shown the marked influence of such factors as aeration, temperature, moisture and period of incubation on nitrogen transformations in soil. These factors must be carefully controlled to obtain reproducible results in the laboratory.

A new method for the determination of nitrate production in soils employing rigid laboratory control of such factors as moisture, temperature and size of sample was described by Fitts *et al.* (2). High correlations between nitrate production by this method and nitrogen requirements of corn in Iowa were obtained by Hanway and Dumenil (3).

In the present investigation, nitrate accumulation, which designates the capacity of a soil to accumulate nitrate under controlled conditions, was assessed in relation to the response of wheat to nitrogenous fertilizers in a number of Saskatchewan soils.

MATERIALS AND METHODS

Nitrate accumulation was determined by a modification of the method described by Stanford and Hanway (6). Glass vials 26 mm. in diameter and 95 mm. in length were used as containers during incubation of the soil samples. A hole approximately 3 mm. in diameter was bored in the bottom of the vial, and one of 6 mm. in the plastic cap to permit aeration of the soil during incubation. A glass wool pad, 2 to 5 mm. in thickness, was placed over the hole in the vial. About one-half inch of plaster grade vermiculite (zonalite) was placed on top of the glass wool pad and tapped gently. Ten grams of air-dry soil were placed on top of the vermiculite,

¹Contribution from Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farms Service, Canada Department of Agriculture.

another one-half inch of vermiculite added, and the soil and vermiculite thoroughly mixed by cautiously shaking the vial. The mixture was then leached with three 20-ml. portions of distilled water. The use of krilium, as suggested by Munsen and Stanford (4), aided leaching in fine-textured soils. After leaching, the vial was placed in a gooch crucible holder and excess water removed by suction. The samples were incubated in a humid atmosphere at 30° C. for 14 days and then oven-dried at 105° C. for two to three hours. The soil-vermiculite mixture was shaken out of the vial, suspended by vigorous stirring in 100 ml. of distilled water and filtered. The nitrate nitrogen content was determined by the phenoldisulphonic acid method, using 10 ml. aliquots of the filtrate and reported as p.p.m. N.

Yield data for comparison purposes were obtained from field fertilizer tests conducted by the Department of Soil Science, University of Saskatchewan, the Experimental Farms at Scott, Indian Head, and Regina, and the Soil Research Laboratory. Thirty-one tests were on fields cropped the previous year, and 30 on fallowed soils. Four of the five soil zones recognized in Saskatchewan were represented, namely: *Brown, Dark Brown, Degraded Black and Black*. Part of the data were from rod row plots in a 5 × 5 balanced lattice design and part from field strips. For the determination of nitrate nitrogen present and the nitrate accumulation value, composite soil samples were collected from the 0- to 6-inch depth of check plots or strips at the time of seeding. Response to nitrogen fertilization was determined by the yield ratio suggested by Bray (1) and calculated as follows:

$$\text{yield ratio} = \frac{\text{yield in bu./ac. from 20 lb. P}_2\text{O}_5 \text{ treatment}}{\text{yield in bu./ac. from 20 lb. P}_2\text{O}_5 + 20 \text{ lb. N treatment}} \times 100.$$

Thirty-one soil samples, mostly from the stubble test fields containing less than 5 p.p.m. N as NO₃, were used in a greenhouse experiment. Composite samples were collected from the 0- to 6-inch depth of the various fields, air-dried, ground to pass a 4-mesh sieve, thoroughly mixed and 2000-gm. aliquots placed in half-gallon glazed crocks. Phosphorus was added to all crocks at a rate of 48 lb. P₂O₅ per acre. Thatcher wheat was seeded, and thinned to 25 plants per crock. The crops were harvested after a 30-day growth period, the plants being cut just above the soil surface. The weight and nitrogen content of the dry tissue were determined and the nitrogen uptake per crock calculated. Four replicates were used, the determinations being made on the individual samples.

RESULTS AND DISCUSSION

The relationship between the response to nitrogenous fertilizers on fields cropped the previous year and the 2-week nitrate accumulation value is shown in Figure 1. The correlation coefficient of 0.846 was significant at the 1 per cent level. The relationship was curvilinear and the regression equation was expressed by $y = 1.91x - 0.016x^2 + 35$, where y represented the yield ratio and x the nitrate accumulation. The curve showed that when nitrate accumulation was less than 50 p.p.m. N, response to nitrogen application occurred.

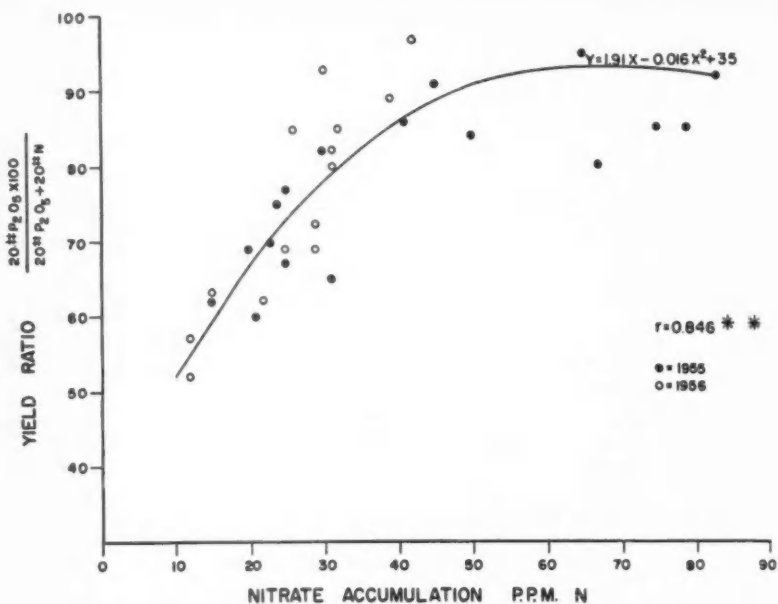


FIGURE 1. Relationship between yield ratios and nitrate accumulation values for soils cropped the previous year.

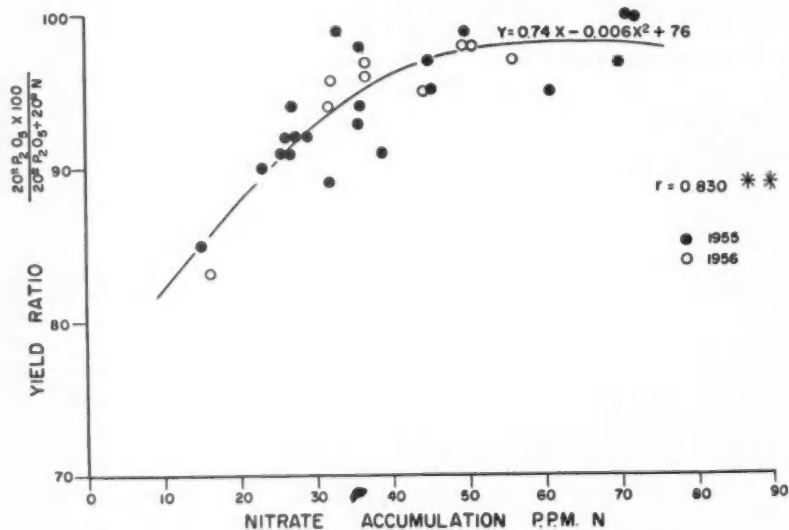


FIGURE 2. Relationship between yield ratios and nitrate accumulation values for fallowed soils.

When the yield ratios for test plots to which nitrogen but no phosphorus had been added were related to nitrate accumulation, the correlation coefficient was 0.560. Although significant at the 1 per cent level, this coefficient was considerably lower than the value of 0.846 obtained where phosphorus had been applied. Owing to this interaction of nitrogen and phosphorus it is considered advisable to include phosphorus in experiments dealing with the effect of nitrogen on crop growth on similar soils.

The yield ratios of fallowed soils, plotted against nitrate accumulation in Figure 2, give a curvilinear relationship with a correlation coefficient of 0.830 significant at the 1 per cent level. The regression equation was $y = 0.74x - 0.006x^2 + 76$ when y represented the yield ratio and x the nitrate accumulation. This curve shows that a response from nitrogen can be expected when the nitrate accumulation is under 40 p.p.m. N for fallowed soils.

When considering the data for the fallowed soils it should be pointed out that nitrate accumulation was determined after the nitrate originally present was leached out. The amount of nitrogen available to the field crops was the sum of the nitrate nitrogen present at seeding time, 10 to 30 p.p.m., plus that produced during the growing season.

In another analysis nitrate nitrogen present at seeding time in the 0- to 6-inch layer was added to the nitrate accumulation value and the total related to the yield ratio. The correlation coefficient was 0.751, significant

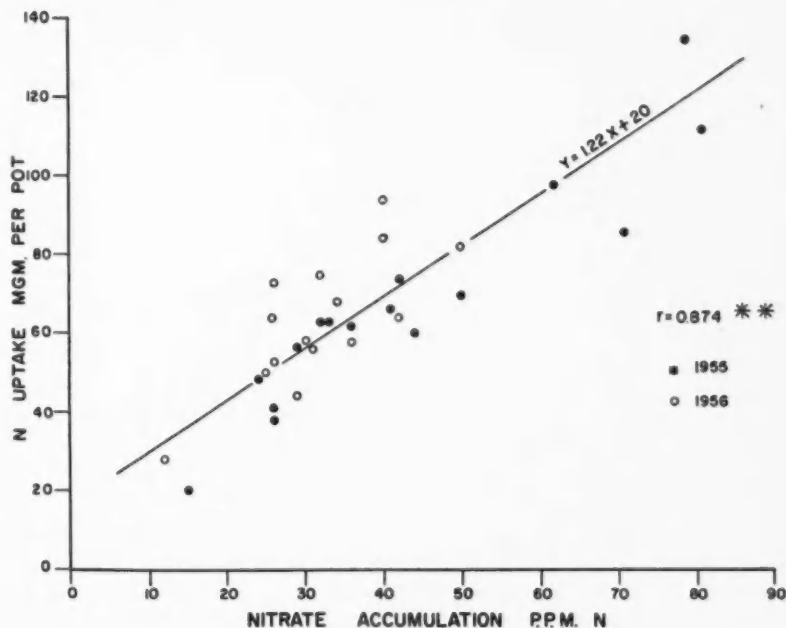


FIGURE 3. Relationship between nitrogen uptake and nitrate accumulation.

at the 1 per cent level with the curve being curvilinear. The lower relationship as compared to the nitrate accumulation alone may be partially explained by the fact that nitrate in the soil below the 6-inch depth was not taken into consideration. The nitrate content of the 0- to 6-inch depth of soil at seeding time was not significantly related to the yield ratio response.

As a further check on the relationship of nitrate accumulation and crop growth, wheat plants were grown in soils to which phosphorus but no nitrogen had been added. The crops were harvested at the end of a 30-day growth period, the dry weight and nitrogen content determined and the total nitrogen uptake calculated. The uptake of nitrogen was plotted against nitrate accumulation in Figure 3. The regression equation for the range of values was $y = 1.22x + 20$ and the correlation coefficient 0.874, significant at the 1 per cent level. The correlation of the dry tissue weights related to nitrate accumulation was 0.611, significant at the 5 per cent level.

The response of wheat to the application of nitrogenous fertilizers is influenced by climatic conditions and management practices. Bearing in mind the variation between climate and management in the four soil zones represented, the relationship between response to nitrogen fertilization and nitrate accumulation is considered to be very good. The determination of the nitrate accumulation value is suggested as a means of predicting the need for nitrogenous fertilizers by cereal crops in Saskatchewan for the data show that a response to nitrogen can be expected when the nitrate accumulation value is under 50 p.p.m. for soils cropped the previous season and 40 p.p.m. for fallowed soils.

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EXTRACTION OF ORGANIC MATTER FROM PODZOLIC SOILS BY MEANS OF DILUTE INORGANIC ACIDS¹

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[Received for publication November 6, 1956]

ABSTRACT

HF, HCl and an HCl-HF mixture at 0.5 per cent concentration for each acid, extracted only 2 per cent of the carbon of the A₀ and up to 96 per cent of that of the B horizon of a podzol soil. Acid concentrations higher than 0.5 per cent (1.25 and 2.50 per cent) were less effective in extracting carbon. Both HF and the HCl-HF mixture were more effective extractants than HCl alone. The amounts of carbon extracted by 0.5 per cent HCl showed a correlation with those of iron and aluminium with maxima occurring in the B horizon extracts.

In a previous note (2) attention was drawn to the fact that large amounts of organic matter could be extracted selectively from a podzolic B horizon by means of a dilute aqueous mixture of HCl and HF. This was in contrast to only very small quantities which could be extracted from the A₀ horizon of the same profile under identical conditions. The present paper describes these experiments in greater detail. In addition to mixtures of HCl and HF at concentration levels of 0.5, 1.25 and 2.50 per cent for each component acid, dilute HCl and HF were used separately as extractants. The amounts of iron, aluminium and silicon extracted simultaneously with the organic matter were also determined. Since most of the work described below was done on the Armadale soil, the effectiveness of dilute HF as an extractant of organic matter from a podzolic B horizon was also tested on another profile, i.e., the Lydgate.

EXPERIMENTAL

Soils Investigated

The profile descriptions of the soils under investigation are as follows:

ARMADALE SERIES

- A₀ 1½-0 in. Very dark brown (10 YR 2/2 moist), fibrous mor. Largely Rhodora debris. Considerable charcoal mixed into upper inch; pH 3.6.
- A₂ 0-6 in. Ashy to light brownish-grey (10 YR 6/1 to 6/2 moist). Loose, loamy fine sand to sandy loam. Structureless; pH 4.3.
- B₂₁ 6-8½ in. Very dark grey (10 YR 3/1 moist) to black (10 YR 2/1 moist). Sand to loamy sand. Some indication of weak, platy-like structure, but very friable and crumbles readily to structureless condition; pH 4.4.
- B₂₂ 8½-10 in. Rusty reddish-brown or dark reddish brown (2.5 YR 3/4 or 5 YR 3/4 moist). Sandy loam. Weak platy structure, moderately friable; pH 4.9.
- B₂₃ 10-20 in. Red to brownish red (2.5 YR 4/4-4/6 moist). Sandy loam, firm to very firm but friable. No distinct structure although tends to break with a platy-like cleavage. Cleavage faces often are blackened by dead root hairs or organic infiltrations; pH 5.0.
- C Below 20 in. Reddish-brown to red. (10 YR to 2.5 YR 3/6 moist). Fine sandy loam to clay loam. Very firm to hard. Contains sandstone fragments, including sandstone relatively high in carbonaceous material; pH 5.2.

¹Contribution No. 336, Chemistry Division, Science Service, Canada Department of Agriculture, Ottawa.

LYDGATE SERIES

- A₀ 6-8 in. Black, fibrous mor; pH 3.8.
A₂ 0-4 in. Pinkish grey (7.5 YR 5/2 moist). Sandy loam, medium granular structure; friable; pH 4.3.
B₂₁ 4-6 in. Dark reddish brown (5 YR 3/2 moist), sandy loam; firm; weakly iron cemented; faint yellowish brown mottles; pH 4.4.
B₂₂ 6-13 in. Dark brown (7.5 YR 4/4 moist). Sandy loam; slightly firm; brown, distinct mottles; pH 4.6.
B₃ 13-24 in. Pale olive (5 YR 6/3 moist.). Sandy loam; firm; medium granular; mottled with light yellowish brown; pH 4.5.
C 24-40 in. Light grey (5 YR 7/2 moist). Sandy loam; moderately firm; medium granular; mottled; pH 4.6.

ANALYTICAL METHODS

The following method was used for the extraction of organic matter: The acids or acid mixtures were added in 100-ml. portions to plastic beakers, each containing 2-gm. samples of soil ground to pass a 100-mesh sieve, stirred and allowed to stand at room temperature for 24 hours with occasional shaking. The liquid was then carefully siphoned off, centrifuged at 2000 r.p.m. for ten minutes to remove suspended solids and the supernatant made up to 100 ml. The suspended solids were returned to the acid-insoluble soil residue and the extraction was repeated twice with further 100-ml. portions of the acid or acid mixture at 24-hour intervals. In order to determine the efficiency of extraction, appropriate aliquots of the acid-soluble extract and portions of the acid-insoluble residue were freeze-dried in each case and the resulting residues analysed for total carbon by the manometric Van Slyke-Folch method (4), using the Van Slyke-Neil apparatus. The sum of the amounts of carbon in the extract and carbon in the residue, as determined in this manner, was in each instance in good agreement with the amount of carbon found in the original moisture-free soil. Freeze-drying rather than evaporation at elevated temperatures, was resorted to in order to minimize losses due to volatilization. Bremner (1) found the manometric Van Slyke-Folch method to be as accurate as the conventional dry-combustion procedure and to have in addition the advantages of being able to deal with microquantities of material and of speed and simplicity.

Total iron, aluminium and silicon in the original soil samples, the acid-soluble extracts and the acid-insoluble residues were determined according to Shapiro and Brannock (3) with the following modifications: Acid-soluble extracts and acid-insoluble soil residues were first freeze-dried. Appropriate portions of the residues so obtained were then weighed out for analysis. For the preparation of solution B, as outlined in the method, 0.1 gm.-samples were used to which 0.5 ml. HClO₄, 1 ml. 1 + 1 H₂SO₄ and 5 ml. HF were added. Samples rich in carbon were incinerated at 400° C. for six hours prior to the acid treatment. The iron-o-phenanthroline colour was measured at 510 mμ instead of at 560 mμ as recommended by these authors. All data are expressed on an air-dry weight basis.

RESULTS AND DISCUSSION

Preliminary experiments were concerned with establishing optimum conditions with regard to the concentration of acids to be used and the number of extractions required. For this purpose mixtures of HCl and

HF were employed at the 0.50, 1.25 and 2.50 per cent (v/v) level for each component acid. Carbon in the extracts was determined after 24 hours of extraction. An inspection of the data in Table 1 establishes 0.5 per cent HCl-HF as the most effective extractant of the three. The data in Table 1 also show a sharp decline in the rate of dissolution of carbon after the first extraction and suggest that three extractions should suffice for all practical purposes to remove most of the carbon brought into solution under given conditions.

Table 2 compares the percentages of total carbon extracted by 0.5 per cent HCl-HF, 0.5 per cent HF and 0.5 per cent HCl from the Armadale profile. The data indicate that none of the three extractants removes significant amounts of organic matter from the A_0 horizon. On the basis of its solubility in these inorganic acids, the organic matter in this podzolic B appears therefore to differ considerably from that in the A_0 horizon. In general, 0.5 per cent HF is more effective in dissolving carbon than 0.5 per cent HCl-HF. Both extractants are definitely more active than 0.5 per cent HCl. It can be concluded that HF is mainly responsible for the high extractive power of the mixture.

Since most of the preliminary work was done on the Armadale profile, it was thought advantageous to test the general applicability of dilute inorganic acid extraction on another profile. The Lydgate, an imperfectly drained podzol, was chosen for this purpose. The extractant was 0.5 per cent HF. As can be seen from the data in Table 3 the pattern of extraction is in general similar to that of the Armadale profile.

TABLE 1.—EFFECT OF ACID CONCENTRATION AND NUMBER OF EXTRACTIONS ON THE PROPORTION OF THE TOTAL CARBON EXTRACTED FROM THE B_{21} HORIZON OF THE ARMADALE PROFILE
(Expressed as per cent of total C in soil)

Concentration of HCl-HF	Number of extractions		
	1	2	3
0.5 %	59.0	67.0	70.0
1.25%	49.0	54.0	56.0
2.50%	48.0	51.0	52.0

TABLE 2.—PROPORTION OF TOTAL CARBON EXTRACTED BY 0.5% HCl-HF, 0.5% HF AND 0.5% HCl FROM THE ARMADALE PROFILE

Horizon	Depth in.	Carbon in original soil mgm./gm.	Percentage of carbon extracted by		
			0.5% HCl-HF	0.5% HF	0.5% HCl
A_0	1½-0	352.0	2	2	2
A_2	0-6	2.0	30	41	0
B_{21}	6-8½	41.7	70	78	42
B_{22}	8½-10	26.7	92	90	70
B_{23}	10-20	8.5	88	96	77
C	below 20	1.3	50	80	50

TABLE 3.—PROPORTION OF TOTAL CARBON EXTRACTED FROM THE LYDGATE PROFILE BY 0.5% HF

Horizon	Carbon in original soil	Percentage of carbon extracted	Colour of extract
	mgm./gm.		
A ₀₁	424.9	5	Colourless
A ₂₄	2.7	3	Colourless
B ₂₁	80.0	67	Deep brown
B ₂₂	47.0	60	Brown
B ₂₃	2.4	87	Light brown
C ₁	1.4	73	Colourless

TABLE 4.—TOTAL IRON, ALUMINIUM AND SILICON IN THE ARMADALE PROFILE (Expressed as per cent of air-dry soil)

Horizon	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂
A ₀	0.63	2.64	23.40
A ₂	0.48	6.31	88.50
B ₂₁	1.88	8.31	72.60
B ₂₂	4.28	9.93	71.78
B ₂₃	3.62	10.81	74.00
C	3.68	11.61	76.29

Table 4 presents percentages of total iron, aluminium and silicon in the various horizons of the Armadale profile. Table 5 gives the percentages of the same elements extracted by 0.5 per cent HCl-HF, 0.5 per cent HF and 0.5 per cent HCl from this profile. The percentages of total iron extracted by both 0.5 per cent HCl-HF and 0.5 per cent HF are of the

TABLE 5.—PROPORTION OF TOTAL IRON, ALUMINIUM AND SILICON EXTRACTED BY 0.5% HCl-HF, 0.5% HF AND 0.5% HCl FROM THE ARMADALE PROFILE (Expressed as per cent of total amounts of each constituent in air-dry soil)

Horizon	Extractant	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂
A ₀	0.5% HCl-HF	51	77	30
A ₂		44	62	13
B ₂₁		58	52	15
B ₂₂		76	62	14
B ₂₃		62	60	13
C		45	43	13
A ₀	0.5% HF	51	67	49
A ₂		48	61	16
B ₂₁		62	61	15
B ₂₂		75	59	16
B ₂₃		61	55	12
C		43	42	13
A ₀	0.5% HCl	11	18	3
A ₂		6	6	2
B ₂₁		12	5	0
B ₂₂		32	19	0
B ₂₃		8	14	0
C		0	3	2

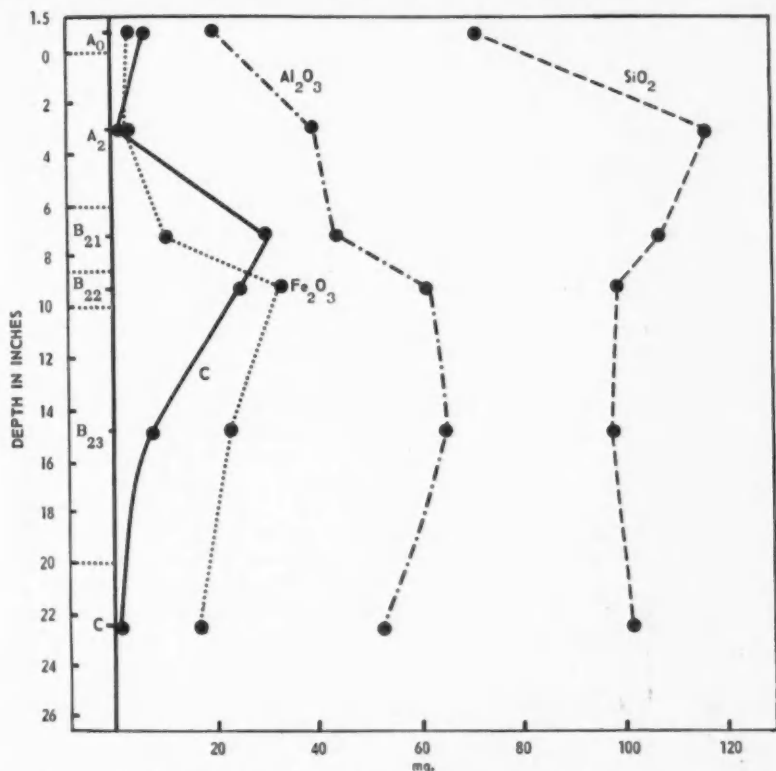


FIGURE 1. Amounts of major constituents extracted by 0.5 per cent HCl-HF from 1-gram samples of horizons of the Armadale soil.

same order of magnitude, show maxima in the acid extracts from the B₂₂ horizon and are considerably higher than those brought into solution by 0.5 per cent HCl. The percentages of total aluminium extracted by 0.5 per cent HCl-HF and 0.5 per cent HF are of the same order of magnitude. They are in general constant throughout the profile, falling off in the extracts from the C horizon and are again significantly higher than those released by 0.5 per cent HCl. The percentages of total silicon released by 0.5 per cent HCl-HF and 0.5 per cent HF appear to be constant throughout the profile except for the A₀ horizon. The amounts of silicon released by 0.5 per cent HCl are very small.

In Figure 1 the amounts of carbon, iron, aluminium and silicon extracted by 0.5 per cent HCl-HF from one gram of Armadale soil are plotted. While the highest amount of carbon is brought into solution from the upper B horizon, the maximum for iron occurs in the B₂₂. The greatest amounts of aluminium were extracted from the B₂₂ and B₂₃ horizons. The amounts of silicon dissolved do not appear to bear any obvious relationship to the quantities of carbon extracted.

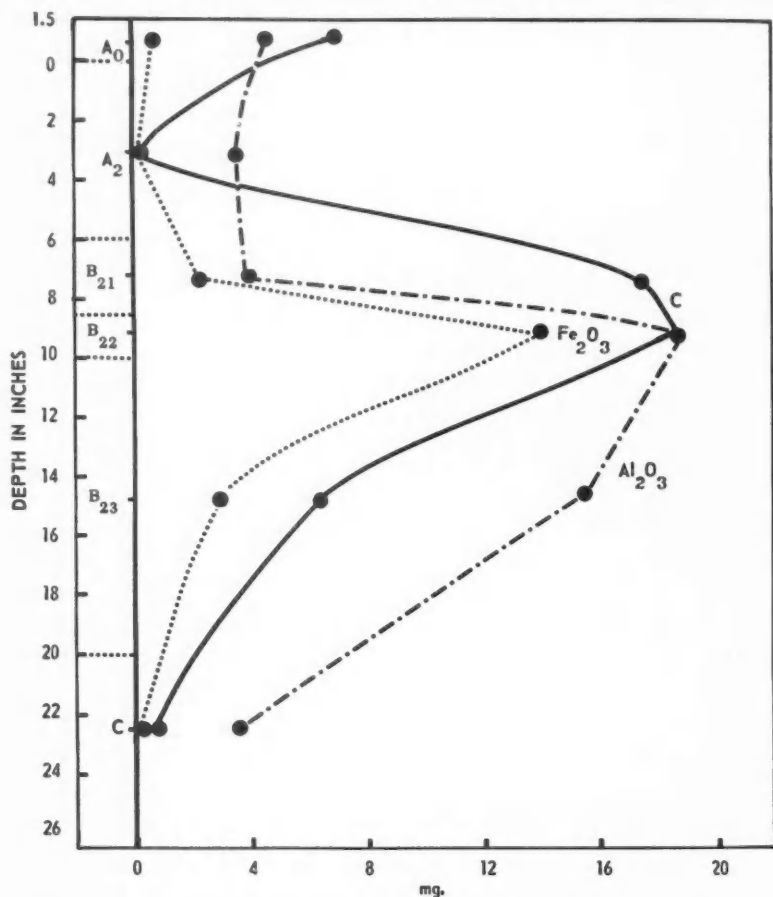


FIGURE 2. Amounts of major constituents extracted by 0.5 per cent HCl from 1-gram samples of horizons of the Armadale soil.

Figure 2 shows the amounts of carbon, iron and aluminium extracted by 0.5 per cent HCl from one gram of Armadale soil. An examination of this figure indicates in general a satisfactory correlation between the amounts of carbon, iron and aluminium extracted.

In this connection it might be permissible to suggest that extractions with 0.5 per cent HCl (approx. 0.06N) give an estimate of the easily soluble iron and aluminium. Furthermore, since this solution dissolves little silicon (Table 5) it might be considered a "mild" reagent as compared to 0.5 per cent HF or the mixture of both acids. An examination of the data in Table 5 and Figures 1 and 2 indicates that 0.5 per cent HF dissolves amounts of iron and aluminium far in excess of the easily soluble iron and aluminium and also appreciable quantities of silicon. This suggests

TABLE 6.—PERCENTAGES OF TOTAL IRON, ALUMINIUM AND SILICON EXTRACTED BY 0.5% HCl-HF, MINUS PERCENTAGES OF THE SAME ELEMENTS EXTRACTED BY 0.5% HCl FROM THE ARMADALE PROFILE

Horizon	Percentage differences		
	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂
A ₀	40	59	27
A ₂	38	56	11
B ₂₁	46	47	15
B ₂₂	44	43	14
B ₂₃	54	46	13
C	45	40	11

strongly that soil minerals are attacked. The data presented in Table 6, showing the differences in terms of percentages between iron, aluminium and silicon extracted by 0.5 per cent HCl-HF and by 0.5 per cent HCl alone, support this point at least in part. Except for the A₀ horizon, the percentage differences for all three elements are, within limits, reasonably constant throughout the profile, suggesting that soil minerals have been dissolved in a systematic manner possibly depending on their solubilities in the acid mixture. Similar results were obtained when calculating the differences between the percentages of these three elements extracted by 0.5 per cent HF and 0.5 per cent HCl respectively.

Since 0.5 per cent HF releases considerably more carbon than 0.5 per cent HCl (Table 2), one might suggest two types of reactions:

(1) Dilute HCl extracts carbon associated with easily soluble iron and aluminium.

(2) Dilute HF, in addition to reaction (1), also attacks soil minerals and releases carbon associated with the latter.

As has been reported earlier (2), only small amounts of carbon could be extracted by water alone.

It is quite possible that the primary function of dilute HCl is dissolution and that of HF dissolution and complexing of iron and aluminium which in turn results in the liberation of carbon and possibly silicon. The known complexing power of the fluoride ion for iron and aluminium appears to be support for such a view. A secondary function of 0.5 per cent HF might be the direct dissolution of some silicon and the possible liberation of carbon associated with the latter. Further investigation is required to clarify these views.

ACKNOWLEDGEMENT

The authors appreciate the assistance of R. Levick and J. G. Desjardins in part of the chemical work.

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THE pH OF NON-CALCAREOUS NEAR-NEUTRAL SOILS¹

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[Received for publication April 23, 1957]

ABSTRACT

Variations in P_{CO_2} have a pronounced effect on both pH and $pH - 1/2pCa$ of non-calcareous near-neutral soils. Consequently it is necessary to specify the P_{CO_2} at which the measurements are made regardless of whether pH or $pH - 1/2pCa$ is used to indicate the acidity of these soils.

INTRODUCTION

The pH of a soil-water suspension depends on the ratio of soil to water. Doughty (1) suggested using only sufficient water to make a paste. This necessitates inserting the saturated KCl bridge of the reference electrode into a fairly concentrated clay suspension, and this may introduce a significant error from a liquid junction potential (5). If, on the other hand, a considerable quantity of water is added to the soil, the system is entirely different from that which exists in the field. In some laboratories (6) a sufficient amount of a neutral salt is added to give a coagulated suspension and the saturated KCl bridge is placed in the supernatant liquid above the solids. The pH value thus obtained depends on the concentration of the added salt so that the problem of interpreting the results in terms of field conditions is not eliminated.

Reasoning on the basis of the properties of the inter-face between the soil solution and the negatively charged surfaces of the soil particles, Schofield and Taylor (7) claimed that the value of $pH - 1/2pCa$ should be independent of both the ratio of soil to water and the concentration of $CaCl_2$ added to the suspension (at least up to 10^{-2} molar). Since pCa represents the negative logarithm of the activity of the calcium ions in solution, $pH - 1/2pCa$ is a measure of the activity of $Ca(OH)_2$ and therefore is a measure of the acidity of a soil. However, the activity of $Mg(OH)_2$ also has a bearing. Consequently, Schofield and Taylor (7) used $pH - 1/2p(Ca + Mg)$ which is constant for a soil providing $pH - 1/2pCa$ and $pMg - pCa$ have constant values. They called this the lime potential of a soil and showed that it was independent of the $CaCl_2$ concentration with relatively acid soils.

With calcareous soils, both the pH and $pH - 1/2pCa$ of a soil-water suspension are controlled by the solubility of the solid $CaCO_3$ present, which in turn is dependent on the partial pressure of CO_2 (8, 9).

With non-calcareous soils which are more or less buffered near neutrality, even if the pH is determined at a known partial pressure of CO_2 (P_{CO_2}), there is no way by which this value can be translated to some other concentration of CO_2 . It seemed worthwhile, therefore, to investigate the effect of P_{CO_2} on $pH - 1/2pCa$ and $pH - 1/2p(Ca + Mg)$.

¹ Contribution No. 355, Chemistry Division, Science Service, Canada Department of Agriculture, Ottawa

EXPERIMENTAL

Analytic Methods

The five soils used in the experiments were air-dried and screened through a 2-mm. sieve, stones being discarded. Loss on ignition was determined by heating at 450° C. for three hours, after drying the soils overnight at 105° C. Exchangeable cations were removed from the soil by extracting with a neutral normal ammonium acetate solution. The hydrogen was estimated by titrating aliquots of the extracts with a standard solution of NH_4OH to the original pH of the ammonium acetate. Calcium and magnesium were determined by the EDTA method after separation of calcium as the oxalate. The calcium oxalate precipitate was dissolved in dilute HCl.

Samples of soil were mixed with distilled water and with solutions of CaCl_2 at three different concentrations, in an atmosphere in which the P_{CO_2} was carefully controlled. The ratio of soil to water was 1:2.5 by weight and the suspensions were shaken mechanically for 48 hours.

CO₂ Concentrations

To obtain atmospheres of known P_{CO_2} , ordinary laboratory air from a compressor was bubbled through NaOH solution (two columns, in series) to remove CO_2 and then through H_2SO_4 to remove moisture and ammonia. The purified air was then passed through a fine capillary under constant pressure to give a constant rate of flow, and into a large bottle, while CO_2 or a CO_2 — N_2 mixture was led through another fine capillary under constant pressure into the same bottle. From the bottle the gas was passed over the suspensions.

The concentration of CO_2 was varied by changing the pressure of CO_2 or CO_2 — N_2 on the fine capillary. The flow of gas with the desired concentration of CO_2 was maintained constant at one litre per minute, as indicated by a flowmeter built into the system. The actual concentration was determined for each experiment by absorbing the CO_2 in the gas stream in a weighed tube of ascarite. The concentration of CO_2 was calculated from the weight of CO_2 absorbed in a measured length of time.

When the desired atmosphere was established, the flow of gas was shunted over the samples by means of a two-way stopcock. There was no opening in the system aside from a small exit tube at the end of the train so that the P_{CO_2} in the atmosphere in contact with the suspensions could be maintained constant.

After shaking was completed a part of each suspension was filtered and the filtrate analysed for calcium and magnesium. The remainder of each suspension was used for pH determinations.

pH Determinations.

All pH measurements were made with a Cambridge meter graduated to 0.02 of a pH unit. The suspensions were allowed to settle for a few minutes before the electrodes were inserted. The saturated KCl bridge of the reference electrode was always kept near the top of the suspensions so that when the clays were coagulated it was in the clear

TABLE 1.—SOME CHARACTERISTICS OF THE SOILS USED
(RESULTS ON AIR-DRY BASIS)

Soil	pH	Loss on ignition %	Exchangeable cations me. per 100 gm. soil				Texture
			Ca	Mg	H	Total	
1	6.80	7.14	17.8	4.7	2.2	24.7	clay loam
2	6.42	12.35	26.2	4.2	3.3	33.7	clay loam
3	6.75	4.05	6.6	1.8	1.2	9.6	sandy loam
4	7.50	13.99	34.9	2.5	0	37.4	sandy loam
5	7.21	22.65	51.7	3.6	1.9	57.2	sandy loam

TABLE 2.—CONCENTRATIONS OF CA+MG AND PMG-pCA AS AFFECTED BY
VARIOUS CONCENTRATIONS OF CO₂ AND CaCl₂*Partial Pressure of CO₂ (Pco₂)*

Soil	CaCl ₂ x10 ³ M	0.0004 atm.		0.001 atm.		0.05 atm.	
		Ca+Mg x10 ³ M	pMg-pCa	Ca+Mg x10 ³ M	pMg-pCa	Ca+Mg x10 ³ M	pMg-pCa
1	0	1.44	0.45	1.44	0.51	2.34	0.47
1	1	1.84	0.47	2.05	0.49	3.46	0.49
1	5	6.08	0.54	6.02	0.52	7.28	0.53
1	10	10.99	0.57	10.91	0.54	11.98	0.56
2	0	1.26	0.67	1.34	0.66	2.22	0.64
2	1	2.02	0.65	2.09	0.64	3.23	0.67
2	5	5.78	0.71	6.00	0.64	6.50	0.65
2	10	10.00	0.68	8.05*	0.63	12.22	0.71
3	0	0.78	0.27	1.03	0.36	1.75	0.38
3	1	1.55	0.40	1.84	0.35	2.62	0.38
3	5	5.43	0.54	5.37	0.55	6.59	0.50
3	10	10.53	0.64	10.68	0.67	11.51	0.71
4	0	1.44	0.83	2.53	0.85	4.24	0.87
4	1	2.34	0.77	3.21	0.85	4.78	0.89
4	5	6.07	0.83	6.75	0.88	8.65	0.87
4	10	11.17	0.95	12.15	0.90	12.87	0.90
5	0	1.60	0.84	3.06	0.87	3.87	0.86
5	1	2.69	0.98	3.95	0.84	4.47	0.80
5	5	lost	lost	7.33	0.85	8.28	0.87
5	10	11.08	0.84	12.50	0.87	13.26	0.90

* The CaCl₂ concentration in this case was 8.3×10^{-3} M instead of the usual 10×10^{-3} M.

supernatant liquid. An atmosphere containing the same concentration of CO₂ as that used in the shaking was passed over the suspensions while the pH measurements were made.

Activities of Calcium and Magnesium Ions

The activities of the ions were estimated by means of the Debye-Huckel equation for activity coefficients,

$$-\log f = \frac{0.5 z^2 \sqrt{u}}{1 + B \sqrt{u}}$$

where f is the activity coefficient, z is the valence of the ion, u is the ionic strength and B is a constant. The values of B used were 1.9 for Ca and 2.6 for Mg (2). It was assumed in estimating u that the cations in solution were Ca and Mg only and that electric neutrality was due to monovalent anions.

RESULTS

Some characteristics of the five soils are presented in Table 1. Two of the samples were clay loams and three were sandy loams. The pH values, which were obtained after mixing the soil-water suspensions, while exposed to the laboratory air for only 20 minutes, showed that the soils ranged from slightly acid to mildly alkaline in reaction. Calcium was the major ion in the exchange complex and all but one of the soils contained some exchangeable hydrogen. The five samples represented soils with low exchange capacity because of low organic matter and clay content, soils with relatively high exchange capacity due to high clay content, and soils with high exchange capacity from a high organic matter content.

Table 2 summarizes the results from the Ca and Mg analyses of the solutions separated from the suspensions after 48 hours' mixing under controlled atmospheres. The addition of CaCl_2 increased the concentration of both Ca and Mg in solution so that $\text{pMg}-\text{pCa}$ remained fairly constant for all but one of the soils. However, with soil No. 3 there was a definite increase in $\text{pMg}-\text{pCa}$ as the concentration of CaCl_2 was increased. This was not surprising because of the low amount of exchangeable Mg in this soil (Table 1). In fact, a calculation showed that for $\text{pMg}-\text{pCa}$ to be the same when the salt concentration was 10×10^{-3} molar as when no salt was added would require more Mg than was available in the exchange complex. Changing the PCO_2 had little if any effect on $\text{pMg}-\text{pCa}$. There was, however, a definite increase in $\text{Ca}+\text{Mg}$ when the PCO_2 was increased from 0.0004 to 0.05 atmospheres when water was used as the dispersion medium.

Table 3 shows that the pH of all suspensions decreased considerably as the CaCl_2 concentration was increased from zero to 10×10^{-3} molar at

TABLE 3.—VALUES FOR pH AND $\text{pH}-1/2\text{pCa}$ AS AFFECTED BY VARIOUS CONCENTRATIONS OF CO_2 AND CaCl_2 *Partial pressure of CO_2 (PCO_2)*

Soil	CaCl_2 $\times 10^3 \text{M}$	0.0004 atm.		0.001 atm.		0.05 atm.	
		pH	$\text{pH}-1/2\text{pCa}$	pH	$\text{pH}-1/2\text{pCa}$	pH	$\text{pH}-1/2\text{pCa}$
1	0	7.42	5.87	7.20	5.66	6.70	5.25
1	1	7.23	5.73	7.18	5.70	6.66	5.28
1	5	6.90	5.63	6.90	5.62	6.48	5.24
1	10	6.77	5.61	6.75	5.58	6.38	5.23
2	0	7.01	5.46	6.92	5.39	6.53	5.09
2	1	6.86	5.42	6.74	5.29	6.44	5.07
2	5	6.58	5.32	6.49	5.23	6.35	5.10
2	10	6.46	5.30	6.37	5.18	6.22	5.09
3	0	7.57	5.88	7.33	5.71	6.59	5.07
3	1	7.34	5.80	7.12	5.61	6.52	5.08
3	5	6.94	5.65	6.83	5.54	6.37	5.10
3	10	6.80	5.64	6.74	5.58	6.28	5.13
4	0	8.09	6.56	7.44	6.04	6.98	5.68
4	1	7.91	6.49	7.37	6.01	6.93	5.65
4	5	7.67	6.42	7.14	5.92	6.81	5.63
4	10	7.52	6.39	7.05	5.93	6.69	5.58
5	0	7.93	6.44	7.50	6.13	6.96	5.64
5	1	7.77	6.39	7.37	6.05	6.92	5.62
5	5	7.53	6.30	7.27	6.06	6.76	5.58
5	10	7.40	6.28	7.13	6.01	6.65	5.54

constant P_{CO_2} . There was also a decrease in pH when the P_{CO_2} was increased at constant $CaCl_2$ concentration. The effect on $pH-1/2pCa$ from increasing the $CaCl_2$ concentration was not consistent. With the lowest P_{CO_2} , the value of $pH-1/2pCa$ decreased with increasing salt concentration but to a much lesser extent than did the pH. When the P_{CO_2} was 0.05 atm. the concentration of salt used had only a small effect; it appeared sometimes to decrease and sometimes to increase this value. There was a consistent decrease in $pH-1/2pCa$ as the P_{CO_2} was increased with constant $CaCl_2$ concentration and this decrease was almost as great as the corresponding decrease in pH.

DISCUSSION

The $pH-1/2p(Ca+Mg)$ values were calculated but were not included in the tables because they showed the same picture as the $pH-1/2pCa$ values. Even with No. 3, where $pMg-pCa$ increased significantly with increasing $CaCl_2$ concentration, the $pH-1/2p(Ca+Mg)$ values were not sufficiently different from the corresponding $pH-1/2pCa$ values to warrant discussing them separately.

With respect to the effect of the concentration of $CaCl_2$ on pH and $pH-1/2pCa$, it can be said that this was much more pronounced on the former than on the latter. In fact, when P_{CO_2} was 0.05 atmospheres, $pH-1/2pCa$ remained constant with two of the soils, increased with one of them and decreased with the other two as the salt concentration was increased. It should be noted, however, that there was very little difference in the $pH-1/2pCa$ values between the 5×10^{-3} and the 10×10^{-3} molar $CaCl_2$ experiments, providing P_{CO_2} was kept constant. A possible explanation of the apparent effect of $CaCl_2$ on the values of $pH-1/2pCa$ lies in the coagulating properties of electrolytes. When the concentration of $CaCl_2$ was either 5×10^{-3} or 10×10^{-3} molar the solids were well coagulated so that it was the pH of the supernatant liquid which was measured in these experiments. In the systems in which the concentration of $CaCl_2$ was low, the suspensions were dispersed and both the glass and the reference electrodes were inserted in more or less concentrated clay suspensions. The pH measured in such a way is generally different from that measured in the liquid at equilibrium with the suspension. This difference may be caused by a liquid junction potential at the saturated KCl bridge of the reference electrode, or it may be the result of a real difference in hydrogen ion activity between the suspension and its equilibrium solution (3, 4, 5). In any event it should not be surprising that the $pH-1/2pCa$ values calculated from pH measurements made in dispersed systems (low salt concentrations) should be different from those based on measurements made in coagulated systems (high salt concentrations). Consequently, the increase in $pH-1/2pCa$ with the low $CaCl_2$ concentrations may not be a reflection of a real change in the activity of $Ca(OH)_2$ in the solutions.

The main objective of the investigation, however, was to determine whether $pH-1/2pCa$ of a non-calcareous near-neutral soil was independent of P_{CO_2} . Regardless of whether or not the system were coagulated with $CaCl_2$, increasing P_{CO_2} caused a decrease in pH. The increased Ca con-

centration from higher P_{CO_2} was not sufficient to offset the corresponding decrease in pH and thus keep $pH-1/2pCa$ constant. It is, therefore, necessary to specify the P_{CO_2} at which the measurements are made, regardless of whether pH or $pH-1/2pCa$ is used to indicate the acidity of these soils.

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SOIL CONDITIONERS—THEIR EFFECT ON COARSE-TEXTURED SOILS, CROP YIELDS AND COMPOSITION¹

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[Received for publication September 7, 1956]

ABSTRACT

Crop response to soil structural changes caused by soil conditioner amendments was studied in several different sandy soils of New Jersey. The response varied with the crop and treatment. Those chemicals that were slightly hydrophobic were most effective and generally crop response was greatest on these treatments. Cations such as Na may be added in large amounts as part of some conditioners, and this may result in reduced uptake of other nutrients such as Mg. and K. Except for this effect, conditioners did not reduce nutrient uptake by plants. When elements such as Na and N are added in large amounts as part of some conditioners, there may be an increased uptake of these nutrients.

Catalin and VAMA conditioners produced a dry surface mulch which appeared to reduce evaporation. Moisture reserves were, therefore, preserved through a drought and this resulted in increased growth of crops over those grown on other treatments. Cultural practices destroyed the stability of the conditioned aggregates, since in most cases the effect had largely disappeared by the third growing season. Chemicals which were effective in soil aggregate stabilization were also effective as anti-crustants when crusting was a problem.

INTRODUCTION

A large volume of literature concerning the use of synthetic soil conditioners has rapidly accumulated since their introduction by Monsanto Chemical Company in 1952 (2). Quastel has made a complete review of this literature up to 1953 (6). Since that time, other reviewers have published their reports (1, 4, 7).

The advent of these conditioners heralded a new phase in the study of soil structure. While their general use in agriculture is limited by high cost, they are of great value in the evaluation of soil structure. This method was used on some of the light-textured, intensively cultivated, poor structured, vegetable soils of New Jersey. Conditioner chemicals were studied on the basis of the longevity of stabilized aggregates, their aggregate stabilizing and anti-crusting properties, as well as their effect on the composition and yields of various field crops.

MATERIALS AND METHODS

Outdoor Cylinder Studies

In the summer of 1952, soil from the A horizons of Sassafras sandy loam, Croton silt loam, Parsippany loam, and Penn loam, was placed in steel drums (24-in. diameter, 48-in. deep, both ends removed) that were set in the soil so that each upper rim protruded approximately 4 inches above the ground. The insides were heavily coated with asphalt before

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the soil was added. The surface 6 inches of soil was limed to pH 6.5 and treated with powdered conditioners, VAMA and S-64, at rates of 1000, 2000, and 4000 lb. per acre. S-64 contained N in the amide form, and its N content was compensated for in the checks and low-rate treatments with $(\text{NH}_4)\text{NO}_3$, so that all plots received an equivalent of 1000 lb. of 10-10-10 an acre. Soil samples for aggregation studies were collected after placing the soil in cylinders, and every 6 months thereafter for 24 months. In 1953, sweet potatoes, and in 1954, lima beans, were used as indicator crops. Tissue samples were collected from the sweet potato plants.

Marlboro, N.J., Depth Study

In the spring of 1953, a field study was established on Collington sandy loam at Marlboro, N.J. The plots were fertilized with 100 lb. each of N, P_2O_5 and K_2O per acre. Some of the N was added in the amide form as part of some of the polymers. The soil had been previously limed to pH 6.5. Conditioner treatments were in duplicate with plots 16×65 feet randomized in two blocks.

Conditioners VAMA, S-64, S-68, S-69, and Catalin were incorporated into the soil at the rate of 2000 lb. an acre as follows: The appropriate amount of powder was spread by hand over the dry soil surface which was immediately rototilled twice. Liquid conditioners were very viscous and were diluted with sufficient water to facilitate spreading the appropriate amount of active ingredient over the plot surface prior to rototilling. Some important properties of the chemicals used are described in Table I. VAMA, Catalin and S-70 are hydrophobic, while S-64, S-68 and S-69 possess this property to a lesser degree.

TABLE I.—SOME PROPERTIES OF CONDITIONERS USED

1. S-17	—Half ammonia salt, half amide, derived from copolymer of methyl vinyl ether and maleic acid; 7% NH_4 ; functional groups, $-\text{COONH}_4$, $-\text{CONH}_2$.
2. S-64	—S-17 type mixture; 85% S-17, 15% calcium resinate; cations, 3.1% NH_4 , 2.6% Ca, 3.7% amide N.
3. S-68	—S-17 type mixture; 75% S-17, 25% rosin; cations, 0.1% H, 4.7% NH_4 .
4. S-69	—S-17 type mixture; 65% S-17, 35% rosin; cations, 0.1% H, 4.1% NH_4 .
5. S-70	—The free acid of S-17; $\text{C}_7\text{H}_{10}\text{O}_6$; functional groups, 2 (COOH); 600 me. H/hg.
6. S-74	—Alkyl vinyl ether homopolymer (polyvinyl isobutyl ether) supplied as 10% dispersion in water; non-ionic.
7. Catalin	—Na salt of a styrene copolymer.
8. VAMA	—A mixture of calcium hydroxide and a copolymer of vinyl acetate, and the partial methyl ester of maleic acid (8% ca.)
9. HPAN	—Hydrolyzed polyacrylonitrile (9% Na).
10. Darex	—VAMA copolymer.
11. IBMA	—Isobutylene, maleic acid copolymer (half amide, half ammonia salt).

Soil samples for aggregation studies were taken 3 weeks after the conditioners were incorporated, and at 6-month intervals thereafter. Table beets were planted in all plots. At the time of harvest, four 10-foot rows were topped and weighed, and leaf samples were collected for analysis. One week after the beet harvest, the plots were planted with celery sets.

These plants were harvested and sampled at maturity in a manner similar to that used for the table beets. During the summer, the plots received three 1-inch irrigations from an overhead system. In the spring of 1954, 200 lb. of $MgSO_4$ were distributed over the area and the plots were then seeded to spinach. Germination was spotty and no yields were taken. However, tissue samples were collected for analysis.

New Brunswick, N. J., Depth Study

A second depth study was established on Sassafras sandy loam in the spring of 1953 at New Brunswick, N. J. A 5-10-10 fertilizer was applied at the rate of 2000 lb. an acre and ploughed under. The soil was limed to pH 6.5 and treatments were in triplicate; plots were 10 × 65 feet and randomized in three blocks.

Conditioners VAMA, HPAN, S-64, S-69, Catalin and Darex were incorporated at the rate of 2000 lb. an acre as previously described. Soil samples for aggregation studies were taken approximately 2 weeks after the test was established, and every 6 months thereafter for 24 months. Each plot was divided into four equal portions, with a different crop in each part. In 1953 the crop were sweet potatoes, carrots, tomatoes, and sweet corn. Two weeks before the harvest time of each crop, tissue samples were collected for analysis. In 1954 the crops were potatoes, carrots, tomatoes, and sweet corn. Tissue samples were not collected. These plots were not irrigated during 1953 or 1954.

Crust Prevention Studies

Treatments for crust prevention were accomplished as follows: The conditioner was dissolved in water to the desired dilution and sprayed under pressure with a knapsack sprayer directly over the seed row immediately after seeding in a band 4 inches wide.

In 1953 at the College Farm, S-17, IBMA, VAMA, HPAN, Catalin, and Darex were applied over the seed rows of table beets, onions, carrots, parsnips, snap beans, spring lettuce, white clover, and alfalfa. Each chemical was applied as a 0.5 per cent solution at the rate of one gallon per 80 feet of row, in 10-foot rows. Treatments were in quadruplicate.

In 1954, S-70, S-74, and IBMA were applied over the seed rows of table beets and snap beans. S-70 and IBMA were used in 0.5 per cent, and S-74 in 12.5 per cent solutions. All treatments were replicated four times in 10-foot rows. The rate of application was one gallon of solution in 80 feet of row.

Analytical Methods

The statistical analysis methods used to evaluate data obtained from some of the tests were those outlined by Patterson (5).

The stability of aggregates was determined by a modification of the Yoder technique (10). Representative samples were air-dried and sieved to separate the 5.0–2.0 mm. fraction. Fifty grams of these aggregates were placed on a 0.5-mm. screen, then a 2.0-mm. screen was placed on top. This nest was oscillated 30 times a minute in water with a wet-sieving apparatus that had a stroke of $1\frac{1}{2}$ inches. The dry weight of aggregates

retained after 10 minutes of sieving was expressed as a percentage of 50. Where stones larger than 0.5 mm. were present they were separated after wetsieving. The per cent of aggregates was then expressed on the basis of 50 minus the weight of stones.

The Na, Mg and K contents of plant tissues were estimated using the method of Toth *et al.* (8). Nitrogen was determined using the Winkler modification of the standard Kjeldahl procedure (3).

EXPERIMENTAL RESULTS

Outdoor Cylinder Study

This study was conducted to determine the effect of conditioner chemicals on several New Jersey soils that varied with respect to texture, clay minerals and organic matter content. Table 2 shows some of the important characteristics of soils used in this presentation. Aggregate

TABLE 2.—SOME CHARACTERISTICS OF SOILS USED
Mechanical analysis

Soil	Field pH	Sand	Silt	Clay	Principal clay minerals	Organic matter
		%	%	%		%
Croton silt loam	6.2	25	64	11	Illite and Montmorillonite	2.53
Parsippany loam	4.9	44	42	14	Illite	4.26
Sassafras loam	4.9	32	48	20	Illite and Kaolinite	0.74
Penn loam	4.4	45	45	10	Illite	1.16
Collington sandy loam	5.0	64	19	17	Illite	1.24

TABLE 3.—YIELDS OF CELERY, AND EMERGENCE AND YIELDS OF TABLE BEETS, AS AFFECTED BY CONDITIONER TREATMENT

Treatment	Celery tops	Table beets	
	Yields ¹	Emergence ²	Yields (Roots) ¹
VAMA	19.3	72**	17.5
HPAN	24.4*	81**	19.0
S-64	18.8	115	19.5
S-68	16.6	130	28.7*
S-69	20.6	122	25.5
Catalin	19.2	65**	14.0*
Check	16.8	126	22.3
L. S. D. (5%)	6.5	15	5.7
(1%)	9.8	22	8.5

¹ Total pounds from four 10-ft. rows.

² Average number of seedlings emerging in 10 feet of row.

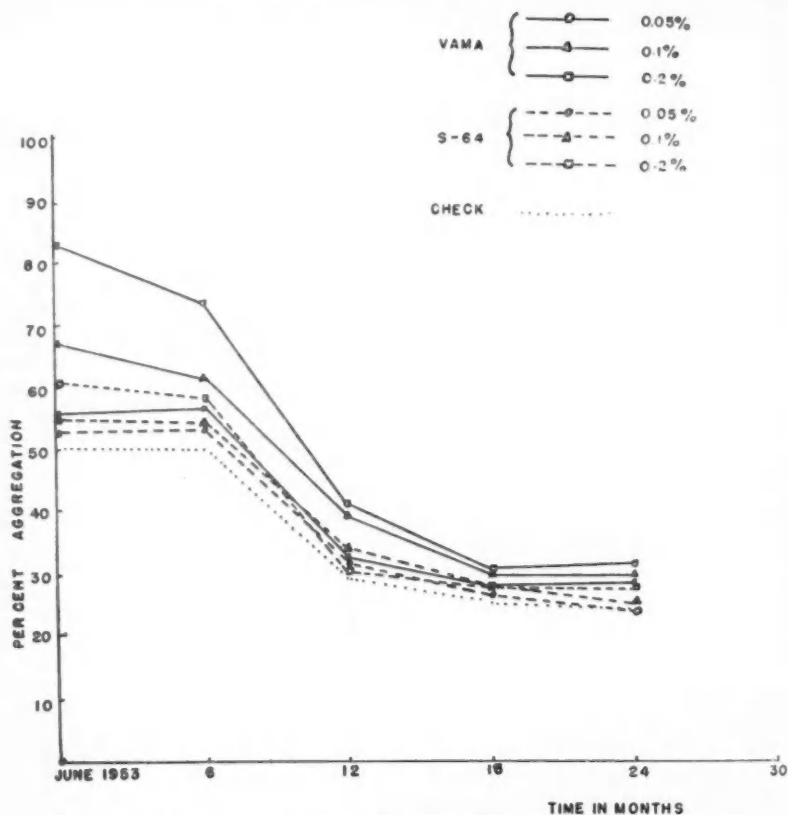


FIGURE 1. Change in aggregation of treated Parsippany silt loam with time.

stability changes for the Parsippany silt loam were typical of the other three soils and are shown in Figure 1. Soil aggregate stability was enhanced on all treatments; generally the higher the rate of application, the greater the aggregate stability. The first winter caused a sharp decline in aggregate stability of all soils. In the Parsippany and Croton soils, the per cent reduction was the greatest. Figure 1 indicates that the treated soils rapidly reverted to near the level of the check soils.

Significant yield increases of crops did not occur with increasing rates of application of conditioner chemicals. Indications of reduced yields with conditioners were noted with lima beans on the Sassafras, Parsippany, and Croton soils. No alteration of nutrient uptake as a result of treatment was noted.

Marlboro Depth Study

Aggregation changes in Collington sandy loam (Figure 2) reflected a rapid decrease in the effectiveness of conditioners. In two seasons aggregation due to Catalin dropped from 92 to 22 per cent and that due to

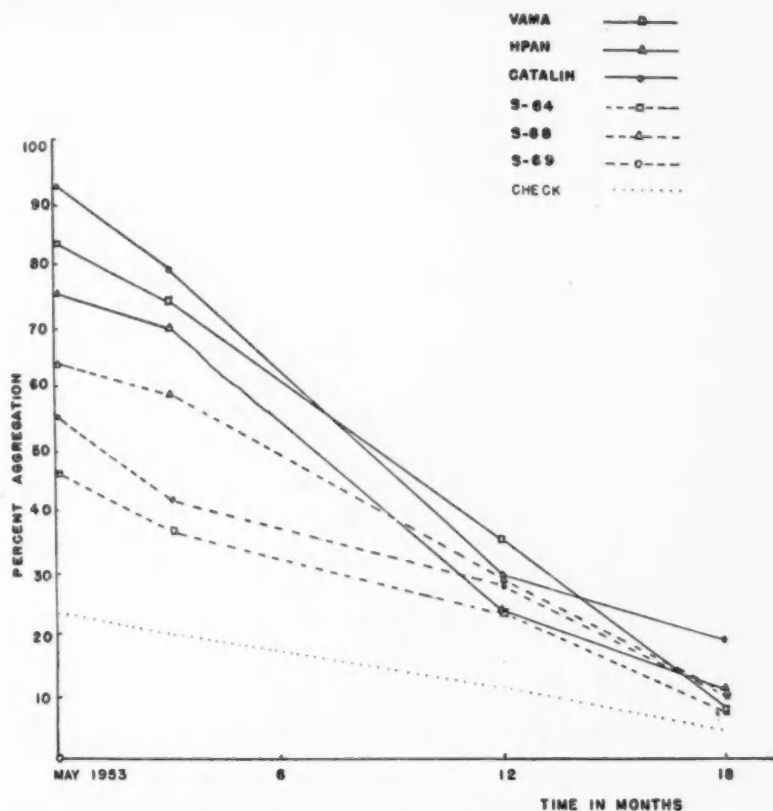


FIGURE 2. Change in aggregation of treated Collington sandy loam with time.

VAMA decreased from 82 per cent to the level of the check plots. Because the effect of conditioners had virtually disappeared by the fall of 1954 the plots were discontinued.

TABLE 4.—N, Na, Mg AND K, CONTENT OF TABLE BEETS AS AFFECTED BY CONDITIONER TREATMENT

Treatment	N	Na	Mg	K
	%	%	%	%
VAMA	2.7	2.6	0.26	8.0
HPAN	2.9	4.4	0.07	6.2
S-64	3.0	2.6	0.60	7.8
S-68	3.0	2.1	0.60	7.8
S-69	3.1	2.1	0.70	7.6
Catalin	2.8	4.1	0.27	6.4
Check	2.7	2.6	0.85	8.2

TABLE 5.—YIELDS OF VEGETABLE CROPS AND PER CENT AGGREGATION AS AFFECTED BY SOIL CONDITIONER TREATMENT
(Pounds per plot)

Treatment	Percentage of aggregation			Corn		Tomatoes		Carrots		Sweet potatoes 1953	Potatoes 1954
	Interval since application			1953	1954	1953	1954	1953	1954		
	2 wk.	6 mo.	18 mo.								
VAMA	90	86	53	20.9	3.0	134.8**	87.1	42.3	56.6**	52.2*	27.0**
HPAN	82	73	29	19.6	3.3	136.6**	87.4	37.1	44.5	41.2	16.3
S-64	85	54	28	16.5	1.8	118.2	68.7	40.1	49.7	45.4	27.0**
S-69	81	45	27	18.5	1.0	131.2*	77.7	43.1	51.3*	40.8	21.7
Catalin	98	92	61	16.6	7.3**	125.5	91.0**	36.9	55.8**	52.6**	26.8**
Darex	85	78	34	24.9**	2.5	115.7	81.4	32.3	52.3**	35.2	28.0**
Check	25	25	13	18.2	1.5	113.2	83.2	35.2	44.0	36.1	21.5
Significant difference (5%)											
				4.7	2.1	17.4	5.3	8.6	5.9	11.8	3.8
				6.6	3.0	23.4	7.5	12.1	8.3	16.5	5.3

Table 3 indicates that the emergence of table beets in the spring of 1953 on plots treated with VAMA, HPAN, and Catalin polymers was reduced and early growth was seriously retarded. Table 3 also shows that the yields on the plots receiving S-68 were significantly increased at the 5 per cent level. Catalin significantly reduced yields. Celery yields were significantly increased on HPAN plots. Table 4 shows a reduction in Mg and K and increased Na uptake by beets on plots receiving Na polymers such as HPAN and Catalin. N uptake from S-64, S-68 and S-69 treated plots was increased slightly. No other consistent differences were noted. The application of 200 lb. of $MgSO_4$ to all treatments, the following spring, corrected the Mg deficiency.

New Brunswick Depth Study

Aggregation changes in Sassafras sandy loam (Table 5) reflect a rapid decrease in effectiveness of conditioners. The general trends of the treatments were similar to those on the Collington soil at Marlboro. The initial increases in aggregation were large at first sampling but at the end of 18 months had been reduced markedly. The aggregation of the check soil was reduced to nearly one-half of the original value of 25 per cent at the end of 18 months.

VAMA and Catalin polymers gave a dried appearance to the soil surface that persisted for two seasons. Other conditioners varied in this property, but the check soil surface was nearly always damp. In 1954 a serious drought reflected a change in the moisture relationships of the treatments. Those chemicals that were most hydrophobic (VAMA and Catalin) produced a dry soil surface that seemed to reduce evaporation. Growth of all crops in 1954 was seriously retarded because of drought except on Catalin and VAMA treatments. However, infiltration of later rains was greatly reduced on these treatments.

The yields obtained with the different conditioners in the two years are also presented in Table 5. In 1953 Darex caused significant yield increases in corn, HPAN in tomatoes, and VAMA and Catalin in sweet potatoes. No treatment produced an increase in carrot yields. In 1954 VAMA, S-64, Catalin, and Darex produced significant yield increases with potatoes, Catalin with tomatoes, and VAMA, S-69, Catalin, and Darex with carrots.

TABLE 6.—NUMBER OF SEEDLINGS EMERGING¹ IN RELATION TO SOIL CONDITIONER TREATMENT (COLLEGE FARM, 1953)

Crop	Treatment							L.S.D.	
	S-17	IBMA	VAMA	HPAN	Catalin	Darex	Check	5%	1%
Beets	101	94	80**	87	66**	84*	94	10	14
Onions	33**	28	36**	40**	31*	40**	20	9	12
Carrots	94**	99**	43**	81**	71**	33**	54	10	14
Parsnips	95**	33**	45**	40**	115**	88**	15	8	11
Snap beans	55	44	46	59*	53	64**	47	11	15
Spring lettuce	98**	111*	88**	158	153	103**	139	21	29
White clover	45**	110*	78	78	102**	108**	74	18	25
Alfalfa	82*	101	80*	105	106	74**	109	25	34

¹ Average number of seedlings emerging in 10 feet of row.

TABLE 7.—EMERGENCE OF TABLE BEETS AND SNAP BEANS WITH RESPECT TO SOIL CONDITIONER TREATMENT

Treatment	Rate	Concentration	Table beet counts ¹	Snap bean counts ¹
S-70	1 gal./80	0.5%	138**	38
S-74	"	12.5%	92	30
IBMA	"	0.5%	115**	28
Check			82	34
L. S. D.	(5%)		14	5
	(1%)		19	—

¹ Average number of seedlings emerging in 10 feet of row.

Tissue analyses showed little variation with treatment for the majority of plant nutrient elements. However, there was a trend toward reduced Mg and K uptake on HPAN and Catalin treatments in the first year crops, but by 1954 this effect had disappeared. There was no increased N uptake from S-64 and S-69 treated plots in either year.

Crust Prevention Studies

Tables 6 and 7 indicate that during the years 1953 and 1954 emergence of some vegetables was enhanced by the use of many of the polymers. On the other hand, VAMA significantly reduced the emergence of beets, carrots, lettuce, and alfalfa; Darex reduced the emergence of alfalfa, lettuce, carrots and beets; Catalin reduced the emergence of beets; IBMA reduced the emergence of lettuce, and S-17 reduced the emergence of lettuce, white clover and alfalfa in 1953. The emergence of beets was increased significantly on the S-70 and IBMA treated rows in 1954.

DISCUSSION AND CONCLUSIONS

The outdoor cylinder study was conducted to determine, in part, the value of soil conditioners in preventing the reduction in aggregation of virgin soils when brought under cultivation. The additions of VAMA and S-64 resulted in marked increases in aggregation over the check soils but this effect was short-lived. After 12 months the aggregation values of all treatments had fallen below the initial value of aggregation of the virgin soil. The aggregation of the check soil had also decreased to approximately 60 per cent of its initial value. These changes can be attributed to reactions related to being brought under cultivation. The Parsippany and Croton soils showed the greatest decline in aggregate stability and incidentally also were the highest in organic matter content.

The four soils used in the cylinder study were chosen because of their dominant clay mineral, texture and organic matter content in an endeavour to determine some relationship between these characteristics and response to soil conditioners. There appears to be a great overlapping influence of these characteristics because the aggregation data did not show any consistent trends, except that the two higher organic matter soils had the smallest initial per cent increase in aggregation in response to conditioners,

and lost this increase sooner. The uptake of inorganic plant nutrients from the four soils was not affected by soil conditioner treatment and crop yields were not significantly altered.

The Marlboro depth trails represented conditions under rather intensive cultural practices. Under such circumstances soil aggregates were subjected to severe breakdown. The sandy texture of the Collington soil added to the short lifetime of treated aggregates. After two seasons most of the polymers had lost their effectiveness. The rapid breakdown of aggregates was attributed to the intensive cultural practices because the stability of the aggregates in the check soil was also markedly reduced.

The large amounts of Na added in some conditioners reduced the Mg and K uptake of crops. This may have caused the retardation of the early growth of table beets at Marlboro. The Mg content of beets from HPAN treated plots was markedly reduced, and the Na content of beets from HPAN and Catalin treated plots was increased over the check plots. Applications of 200 lb. of $MgSO$ an acre remedied this problem, since spinach grown in 1954 showed no reduction in Mg content. Previous work has shown only slight changes in nutrient uptake by plants as a result of conditioner treatment (2, 4, 7). However, these results were obtained on heavier textured soils. On coarser soils the effect of cations added with some conditioners may be much more serious. Even though all plots received equal amounts of N, S-68 and S-69 produced the highest yields. The slow release of N from the amide form in the polymers may be responsible for this effect since the N content of beets from plots treated with these polymers was higher than those taken from the checks. Others have attributed increased yields to this form of N (4, 7). The high Na content of HPAN may be the cause of increased celery yields, since this crop responds to NaCl application.

All conditioners used in the study at New Brunswick on Sassafras sandy loam caused a marked increase in aggregate stability over the checks. In general, Catalin and VAMA caused the greatest increase in the stability and longevity of soil aggregates. Sweet and white potatoes responded to these treatments. Martin's review (4) covers papers that indicate that crops respond to conditioner treatment of heavier soils, provided structure is poor. The above results indicate that yields of crops on sandy soils can also be improved by increasing aggregate stability.

An interesting characteristic of Catalin and VAMA treatments was that of changing the soil moisture relationships. The "dust mulch" produced by the partial waterproofing action of the polymers seemed to reduce evaporation and conserve moisture during a drought. This conservation of moisture is borne out by the fact that plants on these treatments did not wilt during the drought. The only source of moisture was that already in the soil since there was no rain or irrigation during this period. Dust mulches have been previously shown to conserve moisture through reduced evaporation losses (6). It is also possible that the porous soil surface permitted a more favourable environment in which roots grew to deeper moisture reserves. Inorganic plant nutrient element uptake was affected by conditioner treatment in the case of Mg, K and Na, as noted on the Collington soil. This effect was general in all the

soils used in this study. The differences between the different soils was one of intensity rather than kind. In each instance where the Na polymers were used, Mg and K uptake was reduced and Na uptake increased over the check. The VAMA used in this study contained 8 per cent calcium, and on these treatments there was also a trend toward reduced uptake of Mg and K. However, the reduction due to Ca was not as great as that due to Na. There was no increased uptake of Ca from VAMA treated plots in the New Brunswick or Marlboro studies.

While powdered conditioners may be more easily applied in depth treatments, liquids are more easily handled as anti-crustants, since only a narrow band above the seed row is treated. Conditioner chemicals that were slightly hydrophobic were most effective. S-70 is of this type and was very effective, while S-74 (which is very soluble) was not. The rate of application of one gallon of 0.5 per cent solution per 80 feet of row was most economical.

The results on seedling emergence indicate that, where crusting is a problem, anti-crustants may be useful. Other work has borne this out (4, 8).

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A COMPARISON OF SOME TILLAGE METHODS FOR CORN ON BROOKSTON CLAY SOIL¹

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[Received for publication October 4, 1956]

ABSTRACT

Methods of mulch-planting were compared with mouldboard-ploughing methods for corn production at Woodslee during 1953, 1954 and 1955. The tillage treatments were established in second-year alfalfa sod on Brookston clay soil. On the basis of corn yield the conventional ploughing treatments were greatly superior to any mulch-plant method tested during the three years. Soil moisture studies indicated that the effect of the intercrop on the soil moisture supply was the major factor influencing crop yield, but moisture alone did not account entirely for the differences obtained in crop yield. The plough-plant method produced as good corn yields as spring ploughing in 1953 but somewhat less in 1954 and 1955. The results would suggest that an adaptation of the plough-plant method may have possible application as a tillage method for corn on the finer textured soils of southwestern Ontario.

INTRODUCTION

Tillage methods used in the production of grain corn in North America have changed very little since the land was first cropped. These tillage operations have usually involved the use of some type of plough to invert a furrow slice of soil and the use of various types of harrows to prepare a seedbed.

Within recent years a number of research workers have introduced modified methods of preparing soil for corn production. Generally these methods require less equipment traffic on the soil and consequently reduce the time and cost to produce a seedbed. Research (2, 3, 5, 6) indicated that highest corn yields were obtained on ploughed soil and that further tillage after ploughing had little effect on yield.

One of the recently proposed tillage methods, described as mulch planting, included tillage and planting in the same operation (7). Experimental work (8) indicated that methods of mulch-planting in a living sod or in corn stubble decreased corn yield when compared with ploughing followed by additional tillage. Where adequate supplies of nitrogen and water were available for both corn and intercrop (4), corn yields were almost as great on mulch-planted plots as on plots where additional tillage was used. Water and nitrogen, however, did not completely eliminate the detrimental effect of the intercrop on corn yield.

Some effects of tillage on crop yield are attributed to the fact that tillage methods influence soil porosity and moisture. Certain tillage methods (1) have been shown to increase pore space, especially the non-capillary fraction, and consequently have increased the entry of air and water into the soil, accelerated nitrogen formation and allowed for greater root development.

¹ Contribution from the Field Husbandry Division, Experimental Farms Service, Canada Department of Agriculture.

The present study was initiated on Brookston clay soil at Woodslee. The objective was to measure the influence of different tillage methods on yield of grain corn and to determine if any differences in yield could be attributed to changes in soil physical properties resulting from the tillage methods.

MATERIALS AND METHODS

In 1953, 1954 and 1955 studies were carried out on second-year alfalfa sod to compare mulch planting with mouldboard ploughing for corn production. In the mulch-planting operation a strip of soil 20 inches in width was tilled for each corn row and the corn was planted in these strips in the same operation. Since the corn was planted in rows 40 inches apart, a 20-inch strip of untilled sod was left between the mulch-planted rows. Mulch planting was carried out on three different treatments in 1953: one where the alfalfa was left standing; one where the alfalfa was regularly clipped during the growing season, and one on alfalfa that had been disked once before planting. An application of 800 lb. per acre of 2-12-10 fertilizer was made at a depth of 8 inches at the time of planting.

The two other treatments with which the mulch-plant method was compared were spring-ploughed in 1953. In the one case, the spring ploughing was disked twice before the corn was planted. In the other treatment, corn was planted directly into the ploughed soil by allowing the planter shoes to run in the tractor wheel-marks. The ploughing received 800 lb. per acre of 2-12-10 fertilizer, applied broadcast on the surface of the soil before ploughing. Ammonium nitrate was side dressed on all tillage treatments at the rate of 400 lb. per acre when the corn was about 12 inches high.

Fall-ploughed treatments were included in a modified test in 1954 and 1955 and carried out on second-year alfalfa sod. Treatments that were fall-ploughed and spring-ploughed received two or three diskings before the corn was drilled with a corn planter. One mulch-plant treatment was carried out in living alfalfa sod and the other mulch-plant treatment was carried out on fall-ploughed soil. A plough-plant method was carried out as described above.

In 1954 and 1955, 0-12-12 fertilizer was used instead of the 2-12-10 fertilizer that was used in 1953. Nitrogen applications were identical for the three years.

During the three seasons a randomized block design with four replications was used for this experiment. Tillage treatments were compared on the basis of corn yield and certain soil physical measurements.

In 1953, moisture samples were obtained from the tillage plots at the 4-8 inch depth during July. Three-inch core samples were taken from these plots at the 2-6 inch depth within 10 inches of the corn rows in early July and analysed for non-capillary and total pore space. In 1954, only moisture samples were taken from the plots and these were taken at the 4-8 inch depth in early July. In 1955, moisture samples were taken in May and June at the 0-4, 4-8 and 8-12 inch depths for each treatment. Three-inch core samples were again taken in 1955 in June, August and September within 10 inches of the corn rows at the 2-6 inch depth.

Physical measurements were of special interest in this study, since the object of the more recently developed tillage methods was to produce high corn yields with a minimal disturbance of soil structure. Pore space was measured early in the growing season to determine the porosity status on the various tillage methods before plant growth could alter structure. These measurements were made periodically throughout the growing season in 1955 but were discontinued in mid-summer of 1953 because it was not possible to obtain satisfactory core samples during this very dry period. Likewise, soil moisture differences were measured early in the summer before they were affected by seasonal rainfall and plant growth.

Total pore space was measured by two methods in 1955 and the results of both methods are presented. The volume weight method is more precise but total porosity measurements by the Leamer and Shaw method are included to complement the non-capillary pore space results.

EXPERIMENTAL RESULTS

Corn yields for the experiment appear in Tables 1 and 2 for 1953, 1954 and 1955.

TABLE 1.—YIELD OF CORN ON TILLAGE METHODS TEST, WOODSLEE, 1953

Tillage treatment	Yield per acre
	bu.
Plough-planted in spring	68.8
Spring-ploughed and disked twice	64.1
Mulch-planted, alfalfa disked	41.4
Mulch-planted, alfalfa cut	38.1
Mulch-planted, in standing alfalfa	30.7
L.S.D. (0.05)	10.0
(0.01)	14.0

TABLE 2.—YIELD OF CORN ON TILLAGE METHODS TEST, WOODSLEE, 1954 AND 1955

Tillage treatment	Yield per acre	
	1954	1955
	bu.	bu.
Fall-ploughed and disked twice in spring	55.4	103.6
Spring-ploughed and disked twice	51.8	87.7
Mulch-planted directly into alfalfa sod	No yield	12.3
Plough-planted in spring	30.3	84.6
Fall-ploughed and mulch-planted in spring	14.8	72.9
L.S.D. (0.05)	10.7	7.8
(0.01)	15.4	11.0

TABLE 3.—PER CENT MOISTURE AND PER CENT TOTAL AND NON-CAPILLARY PORE SPACE ON TILLAGE METHODS TEST, WOODSLEE, 1953

Tillage treatment	Per cent moisture	Per cent total pore space	Per cent non-capillary pore space
Plough-planted in spring	20.77	47.2	13.4
Spring-ploughed and disked twice	19.86	45.5	10.3
Mulch-planted, alfalfa disked	20.58	44.5	11.4
Mulch-planted, alfalfa cut	18.25	47.3	13.0
Mulch-planted in standing alfalfa	18.49	46.2	13.3
L.S.D. (0.05)	1.30	2.1	2.6
(0.01)	1.78	2.8	3.5

Where corn was mulch-planted directly into alfalfa sod in 1954 the corn plants reached only an approximate height of 18 inches and did not produce any corn. Although yield differences between the three years were large, all ploughing methods were greatly superior to mulch-planting. Ploughing, followed by additional tillage prior to planting was equally as good as plough-planting in 1953 and was better than plough-planting in the succeeding two years.

Per cent moisture and per cent pore space for the various tillage methods appear in Table 3 for 1953.

In the 1953 test, porosity and moisture data indicated no large differences in soil physical condition.

Results of the moisture study for 1954 and 1955 are presented in Table 4 for the five tillage methods.

The data in Table 4 indicate the influence of the tillage treatments on soil moisture at one depth for 1954 and at three depths for 1955.

Pore space measurements from the five tillage treatments are reported in Table 5 for 1955.

Spring ploughing generally showed highest air-pore and total pore space at the three sampling dates. In the June and October samplings non-capillary and total pore space, measured on mulch-planted alfalfa sod, were much lower than on the other tillage treatments.

Correlations were calculated for pore space, moisture and yield values for 1953 and 1955 and the results are presented in Tables 6 and 7. In 1955 only two replicates could be sampled for pore space in the spring while all four replicates were sampled for moisture. Therefore correlations of moisture with yield were calculated for both the two and the four replicates.

Correlation values in Tables 6 and 7 indicate association between only two of the measurements in 1953 but in 1955 correlation was found between yield and pore space and between yield and moisture.

TABLE 4.—PER CENT MOISTURE ON TILLAGE METHODS TEST, WOODSLEE, 1954 AND 1955

Tillage treatment	Sampled July 6, 1954		Sampled May 26, 1955, 6 inches from row		Sampled May 30, 1955, between rows		Sampled June 23, 1955, 6 inches from row			
	4-8"	0-4"	4-8"	8-12"	0-4"	4-8"	8-12"	0-4"	4-8"	8-12"
Fall-ploughed and disked twice in spring	12.62	21.78	26.22	24.77	24.79	24.64	24.67	21.18	25.09	24.78
Spring-ploughed and disked twice	12.62	24.97	20.91	17.48	18.99	22.49	17.96	20.22	23.26	22.90
Mulch-planted directly into alfalfa sod	11.54	22.99	23.18	20.38	23.95	23.42	21.41	20.05	21.37	21.22
Plough-planted in spring	12.39	22.61	20.88	19.78	22.61	19.82	19.23	21.17	23.63	23.10
Fall-ploughed and mulch-planted in spring	13.21	25.22	25.99	25.84	22.73	25.90	24.15	20.03	22.21	23.57
L.S.D. (0.05)	N.S.	N.S.	2.37	2.84	N.S.	N.S.	2.65	N.S.	2.34	1.87
(0.01)	N.S.	N.S.	3.33	3.99	N.S.	N.S.	4.39	N.S.	3.28	2.62

TABLE 5.—PER CENT TOTAL AND NON-CAPILLARY PORE SPACE ON TILLAGE METHODS TEST, WOODSLEE, 1955

Tillage treatment	Sampled June 15			Sampled Aug. 30			Sampled Oct. 14		
	Non-capillary	Total ¹	Total ²	Non-capillary	Total ¹	Total ²	Non-capillary	Total ¹	Total ²
Fall-ploughed and disked twice in spring	18.0	51.4	53.5	24.0	54.5	55.7	16.0	50.8	54.5
Spring-ploughed and disked twice	23.1	55.1	56.2	25.5	53.5	56.5	19.4	51.8	55.1
Mulch-planted directly into alfalfa sod	11.2	44.5	48.0	21.2	51.2	52.6	13.2	48.2	51.2
Plough-planted in spring	22.2	52.3	55.8	24.6	53.8	55.6	19.4	51.6	54.8
Fall-ploughed and mulch-planted in spring	18.4	51.8	53.8	23.6	52.1	55.8	19.0	52.3	55.6
L.S.D. (0.05) (0.01)	3.4 5.6	3.0 5.0	3.0 5.0	N.S. N.S.	1.8 2.3	1.2 1.7	2.0 2.7	1.3 1.9	1.2 1.6

¹ Determined by Leamer and Shaw method.² Calculated from volume weight.

TABLE 6.—CORRELATIONS OF CORN YIELD, NON-CAPILLARY PORE SPACE, TOTAL PORE SPACE AND MOISTURE, 1953

Variates correlated	D.F.	Yield of corn	Per cent total pore	Per cent non-capillary pore
Per cent total pore	18	-0.1803		
Per cent non-capillary pore	18	-0.0644	0.1991	
Per cent moisture	18	0.2472	0.1436	0.5715**

** Significant at the 1% level.

TABLE 7.—CORRELATIONS OF CORN YIELD, NON-CAPILLARY PORE SPACE, TOTAL PORE SPACE AND MOISTURE, 1955

Variates correlated	D.F.	Yield of corn	Per cent total pore	Per cent non-capillary pore
Per cent total pore	8	0.8268**		
Per cent non-capillary pore	8	0.7512*	0.8800**	
Per cent moisture	8	0.6305	0.3080	0.4288
Per cent moisture	18	0.4796*		

* Significant at the 5% level.

** Significant at the 1% level.

DISCUSSION

On the basis of corn yield the conventional ploughing treatments were greatly superior to any mulch-plant method tested during the three years 1953, 1954 and 1955. Yield results for 1954 and 1955 would support the commonly held belief that fall ploughing with normal spring tillage is the most reliable tillage method to use in preparing Brookston clay soil for corn.

Total and non-capillary pore space were much lower on the mulch-plant treatment that was carried out directly in alfalfa sod than on all other treatments. Where mulch planting was carried out on fall-ploughed alfalfa sod both the moisture and porosity status was approximately the same as on the ploughing treatments. However, since mulch planting on fall ploughing failed to produce a corn yield equal to that on the other ploughing treatments it would appear that there was an additional adverse effect from mulch planting not entirely accounted for in this study. Since large quantities of nitrogen, phosphorous and potash had been applied previous to planting, it is unlikely that the lower corn yield on the mulch-plant treatment resulted from a shortage of plant nutrients.

In this study corn yields on the 1955 tillage treatments were correlated with total and non-capillary pore space. In addition, moisture was significantly correlated with yield where moisture samples were taken at the 8-12 inch depth on June 23.

When sampled on June 23 at the 8-12 inch depth, the fall-ploughing treatment followed by normal spring tillage and the plough-planting treatment contained more moisture than was present on mulch planting in alfalfa sod. When samples were taken earlier at the 8-12 inch depth moisture on mulch planting in fall-ploughed alfalfa sod was greater than on the spring ploughing treatments but on June 23 moisture at this depth was approximately the same for these two treatments. Although moisture determinations were not taken at regular intervals throughout the growing season the data suggest that yield may have been limited by lack of available moisture on certain tillage treatments.

The precipitation recorded from May to September inclusive for 1953 and 1954 was 9.36 and 9.40 inches respectively. This was much lower than the preceding 5-year average of 15.09 inches recorded during the same period and lower than the 1955 rainfall of 12.64 inches for this period. The low yields obtained on mulch planting in 1955 under more favourable rainfall would indicate that this tillage method may not be practical for corn on the Brookston clay soil.

The plough-plant method produced the highest yield in 1953 and resulted in intermediate yields in 1954 and 1955. On the basis of both yield and soil physical measurements reported here, it would seem probable that further study would result in the development of plough-plant tillage methods that would be satisfactory for seed-bed preparation on Brookston clay soil.

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AN EVALUATION OF SOME TILE-DRAIN DEPTH AND SPACING FORMULAE FROM THE PHYSICAL PROPERTIES OF SOME ONTARIO SOILS¹

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[Received for publication February 13, 1957]

ABSTRACT

Soil physical properties determined on six fine-textured soil types near Brampton and Chatham were used to solve and evaluate formulae for the depth and spacing of tile drains proposed by Hooghoudt, Walker, Slater, and Dumm. At the Chatham site, measurements of water-table drawdown between tile drains were recorded to compare with Neal's water-table observations of adequate drainage.

A wide difference in soil properties was exhibited between the two study sites. None of the formulae results of spacing agreed precisely. Causes for discrepancies between the results were shown to be due to technical differences in applying data to the formulae and to inherent differences in derivation of the formulae. Data are presented showing the need for a physical criterion of adequate drainage.

INTRODUCTION

A problem of prime importance in tile drainage design is the selection of the proper depth and spacing of lateral tile drains. A number of studies have been made on this phase of design using various soil physical properties as criteria. In recent years hydraulic conductivity and porosity have been recognized as soil properties that directly govern the placement of drains. Drainage engineers, cognizant of the importance of these two properties, have made studies to derive methods for their determination. This paper presents the results of two studies made to determine some physical properties of six fine-textured soils in Ontario and an evaluation of four depth and spacing formulae utilizing these properties.

REVIEW OF LITERATURE

Because of the basic relationship set forth by Darcy's Law between hydraulic conductivity and the velocity of water movement towards drains, much study has been made to develop a suitable method to measure soil hydraulic conductivity. Uhland and O'Neil (12) have described a direct method whereby undisturbed soil cores are removed from the soil and subjected to laboratory hydraulic conductivity tests. This method measures the conductivity in a vertical plane. Luthin and Kirkham (5) have reported on a piezometer method to measure the hydraulic conductivity *in situ* below a water-table. This method accents the horizontal conductivity. Both methods are adaptable for measuring the conductivity of individual strata in a non-uniform soil.

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Early attempts to derive depth and spacing formulae were made by Zunker (15) and Neal (8) by utilizing soil properties that indirectly affect the hydraulic conductivity. Zunker used the soil specific gravity as the criterion to determine the spacing of drains. This formula gives a limited range in spacing because most mineral subsoils, whether well drained sands or poorly drained clays, will have a specific gravity ranging between 2.6 and 2.7 (6). This narrow variation in specific gravity depends not upon factors that affect the drainability of a soil, but rather upon the percentage of individual minerals of varying specific gravity present in the soil. Neal related in nomograph form the depth and spacing of drains to moisture equivalent, clay content, and soil plasticity. It is questionable how far afield the nomographs would apply in view of other experiments (2, 7, 10) that have shown striking examples of the failure of these soil properties to correlate reliably with hydraulic conductivity. Neal recognized the limitations of using these laboratory soil tests but stated that they give a more accurate means of determining the proper depth and spacing than does a mere guess.

More recently, formulae in which hydraulic conductivity and porosity enter explicitly have been proposed by Hooghoudt (4), Slater (11), Walker (14) and Dumm (3). These authors recognized the importance of considering in their formulae not only hydraulic conductivity but the amount of water that must be removed from the soil during a drawdown period. Basically it must be known how much water has to be removed to effect a water-table recession that provides adequate drainage. To date, Neal's observation of water-table conditions that provided adequate drainage is the only one reported in America. He found that crops were not seriously injured if the water-table was held at least 6 inches below the ground surface and was lowered at the rate of 1 foot per day through the second 6-inch depth-interval and at the rate of 0.7 foot per day through the third 6-inch depth-interval. This observation, however, has not been verified by organized research.

Fundamental analysis of ground-water movement into tile drains shows that the flow is essentially horizontal when the soil is underlain by a shallow impermeable layer, and the flow is radial when this layer is at great depths. A combination of the two types of flow occurs when the impermeable layer is at an intermediate depth.

MATERIALS AND PROCEDURE

The first study was made in 1953 at the Brampton Seed Farm on soils mapped as Peel clay loam (*imperfectly drained*), Peel clay loam (*moderately poorly drained*), Caistor clay loam (*imperfectly drained*), Jeddo clay loam (*moderately poorly drained*) and Jeddo clay loam (*poorly drained*)*. The Peel clay loam is a Grey-Brown Podzolic soil developed in lacustrine material underlain by clay till at depths of 3 feet. The Caistor clay loam is also a Grey-Brown Podzolic soil developed from clay till. The Jeddo clay loam is a Dark Grey Gleisolic soil developed from clay till. Soil physical measurements were made at the 1-, 2-, and 3-foot depths on each

* Matthews, B.C., and N. R. Richards. Soils report on Brampton seed farm, Brampton, Ont. Ont. Agr. College. 1949. *Unpublished report*.

TABLE 1.—SOME PHYSICAL CHARACTERISTICS OF SIX SOIL TYPES

Soil type	Depth* (ft.)	Bulky density	Per cent non-capillary porosity	Per cent clay	Vertical hydraulic conductivity (in./hr.)	Horizontal hydraulic conductivity (in./hr.)
Brampton site						
Peel loam (imperfectly drained)	1	1.61	1.9	62	0.017	0.33
	2	1.75	2.1	45	1.2	0.31
	3	1.92	1.1	32	0.021	0.23
Peel clay loam (moderately poorly drained)	1	1.63	1.2	32	0.11	0.24
	2	1.71	1.1	40	0.013	0.13
	3	1.71	0.6	42	—	0.19
Caistor clay loam (imperfectly drained)	1	1.65	1.4	52	0.014	0.0039
	2	1.67	1.0	57	1.3	0.040
	3	1.77	1.9	42	0.022	0.073
Jeddo clay loam (moderately poorly drained)	1	1.51	1.5	54	0.014	1.1
	2	1.56	5.2	47	0.0060	0.091
	3	1.51	2.5	50	0.0092	0.48
Jeddo clay loam (poorly drained)	1	1.47	4.5	50	0.0025	0.74
	2	1.59	1.2	50	0.0022	0.19
	3	1.62	0.69	49	0.0011	1.0
Chatham site						
Brookston clay loam (poorly drained)	1	1.39	8.9	50	5.4	2.4
	2	1.46	6.7	57	1.4	4.3
	3	—	—	—	—	2.0

* Samples taken at these depths.

soil type. At each location, under-the-water-table measurements of the horizontal hydraulic conductivity were made in quadruplicate by the piezometer method. The four piezometers were arranged approximately 6 feet apart in a square. Duplicate soil cores, 3 inches in diameter and length, were obtained at the 1- and 2-foot depths, while single soil cores only were obtained at the 3-foot depths. Difficulties encountered at the 3-foot depth due to presence of till virtually made the procuring of duplicate samples an impossibility. Laboratory studies on the soil cores were made to determine the vertical hydraulic conductivity, bulk density, and percentage of non-capillary porosity at 60-cm. tension using a technique similar to that described by Uhland and O'Neal. Random soil samples at each location were taken and the percentage of clay determined by the Bouyoucos (1) hydrometer method.

The second study was made in 1955 near Chatham on a Brookston clay loam soil (*poorly drained*). This soil type is a Dark Grey Gleisolic soil developed from clay till (9). The same soil properties that were investigated at Brampton were measured at the Chatham site, using similar techniques except that the laboratory determinations on soil cores and determinations of clay content were made only at the 1- and 2-foot depths.

Two tile drains, 50 feet apart and 2 feet deep, were present at the Chatham site. These drains were installed in 1930 and were considered by the farm-owner to provide adequate drainage. Three-eighth inch-diameter observation wells were installed in a row at right angles to, and at varying intervals from, the drains. The wells were spaced closer together near the drains. During the drawdown periods, the water-table elevation between drains was measured with an electrical water-level indicator to determine the rate of drawdown that provided, arbitrarily, adequate drainage.

Appropriate physical measurements were applied to solve formulae proposed by Hooghoudt, Slater, Walker, and Dumm. Each formula was solved by following the procedure outlined by its author. Where assumed values were required, those suggested by the respective author were used. Since the piezometer method has the definite advantage of measuring hydraulic conductivity *in situ*, these values were used in the Hooghoudt, Slater, and Dumm formulae. Laboratory values as determined from soil cores were specifically required for the Walker formula.

Comparative drain depths of 2 feet and 3 feet were selected for the formulae calculations of spacing. The 3-foot depth was selected arbitrarily. The 2-foot depth, however, was chosen specifically to conform to the depth of the installed drains at the Chatham site so that a comparison could be made between the installed and calculated spacing in the Brookston soil.

RESULTS

Table 1 lists the mean values of the physical characteristics of the six soil types. There is a considerable difference in physical characteristics between the soils at the Brampton and Chatham sites. Although the percentage of clay is generally the same at the two sites, the soil at the

TABLE 2.—FORMULA DETERMINATIONS OF DEPTH AND SPACING OF TILE DRAINS

Soil type	Hooghoudt		Slater		Walker		Dunn	
	Depth (ft.)	Spacing (ft.)	Depth (ft.)	Spacing (ft.)	Depth (ft.)	Spacing (ft.)	Depth (ft.)	Spacing (ft.)
Brampton site								
Peel clay loam (imperfectly drained)	2 3	30 43	2 3	24 33	2 3	7 17	2 3	23 36
Peel clay loam (moderately poorly drained)	2 3	15 28	2 3	16 31	2 3	8 —*	2 3	22 36
Caistor clay loam (imperfectly drained)	2 3	1 3	2 3	9 19	2 3	8 20	2 3	10 16
Jeddo clay loam (moderately poorly drained)	2 3	12 22	2 3	13 48	2 3	3 7	2 3	36 57
Jeddo clay loam (poorly drained)	2 3	20 37	2 3	19 70	2 3	0 0	2 3	22 35
Chatham site								
Brookston clay loam (poorly drained)	2 3	144 225	2 3	92 98	2 3	120 —*	2 3	33 53

* Necessary soils data not available.

Chatham site exhibits features, such as lower bulk density and higher non-capillary porosity and hydraulic conductivity, which indicate superior soil structure.

Table 2 shows the depth and spacing results calculated from the four formulae. All four formulae show that the drain spacing increases with increased depth in these soils. A comparison of the spacing results shows that none of the formulae results agrees with another consistently in all six soil types. Generally there is better agreement between the Hooghoudt, Slater, and Dumm results than there is between these three formulae results and the Walker results. This could be expected because the hydraulic conductivity values used in the Walker formula were not the same as those used in the other formulae.

DISCUSSION

An analysis of the discrepancies between the results for the different formulae shows that the causes of variance were due to different techniques of applying soil physical data to the formulae, and to basic differences in the derivation of the formulae. Each author prescribed different methods of applying the hydraulic conductivity data to the formulae. For example, Walker suggested the use of the minimum hydraulic conductivity value to the drain depth; Slater suggested that the hydraulic conductivity value of the soil layer surrounding the drain should be used; and Dumm suggested the use of the weighted average hydraulic conductivity of the soil layers above the barrier layer. There were also different methods used to arrive at a drainage rate to be applied to the formulae. Only a suggested direct drainage rate was required for the Hooghoudt and Slater formulae whereas a water-table recession rate in conjunction with the soil porosity was required for the Walker and Dumm formulae. The porosity factor logically is present in the latter two formulae to account for differences between soils in the volume of water drained for a given water-table recession. Each author, however, differed in his method of determining this volume. Walker used the pore space drained at 60-cm. tension, whereas Dumm used the specific yield.

Discrepancies in the results caused by basic differences in the derivation of the formulae may be attributed mainly to the type of flow assumed. The Slater and Dumm formulae are based on the assumption of horizontal flow while the Walker formula is based on radial flow. Slater, realizing the limitations of his assumption when the barrier layer is at any appreciable depth below the drains, suggested that an arbitrary barrier 2 feet below the drains be assumed to adjust for convergence of flow near the drains. Dumm did not consider that this refinement was perhaps warranted from a practical viewpoint although convergence could be accounted for in his formula. A slightly wider spacing is derived when local resistance due to flow convergence is neglected. Walker's assumption of radial flow is valid only when the barrier layer is absent or at a great depth below the drains. In addition to this limitation, the derivation of Walker's formula implies that the hydraulic gradient causing flow toward a drain is unity. This is not always the case, for in practice it is usually less than unity.

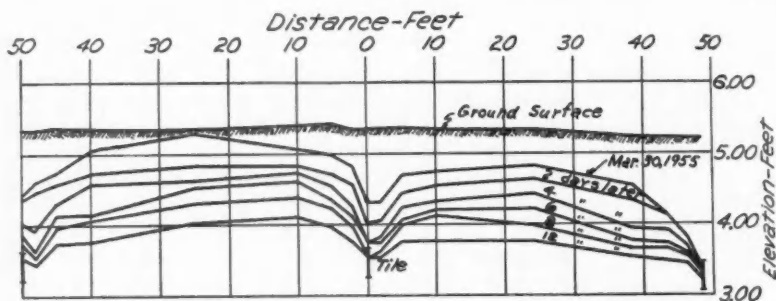


FIGURE 1. Drawdown curves between tile drains at the Chatham site for successive days after a rainfall.

Hooghoudt's three formulae are based on the assumption of horizontal flow, radial flow and a combination of horizontal and radial flow to meet conditions where the barrier layer is at drain depth, at a great depth below the drain, and at some intermediate depth respectively. Hooghoudt's formulae treat the problem of flow to tile drains more precisely than the other formulae. Thus it is evident from the above discussion that there are many sources for variation in the results.

None of the formulae calculations of spacing shown in Table 2 at the 2-foot depth in the Brookston soil agrees with the actual installed spacing of 50 feet. Agreement can only be obtained if the formula used for the calculation is unique, all the assumptions made in deriving the formula are met, and values of the variables entering into the formula are accurate measurements of field conditions. Precise agreement in this study is, therefore, impossible because none of the four formulae is unique; they are at best only close approximations. The basic assumption of homogeneous soil conditions common to all formulae is not met in the Brookston soil because of the presence of structural fissures, and extraneous openings caused by worms and roots. The accuracy with which the soil variable, hydraulic conductivity, can be determined is questioned by the authors and has been questioned in the past by other workers (3, 13, 14). For agreement it is also required that the drainage rate used in the calculations must tally with the actual situation in the field. Unfortunately it was impossible to measure the drainage rate at the study site. Therefore, drainage rates or related water-table recession rates and porosity values used in the formulae were those suggested by the authors. Since Dumm has no specific recession rate to offer for humid conditions, Walker's suggested rate was used in the Dumm formula. These rates, of course, were not necessarily the same as the actual rate in the field. For example, Walker used a recession rate of 0.7 feet per day through the third 6-inch increment of soil in his formula. The drawdown curves in Figure 1 show that the water-table recession rate in the field was a great deal less than that used in his formula.

From an applied point of view, it is of the utmost importance that a drainage rate be used that will provide adequate drainage. Neal's observation of water-table conditions that provide adequate drainage is the

only published criterion that has been expressed in physical terms. Figure 1 shows that at the Chatham site, where the farm-owner considered he was obtaining adequate drainage, the water-table recession rate at the mid-point between drains is a great deal less than that observed by Neal. Thus it seems quite evident that more specific knowledge of the minimum recession rate of the water-table for adequate drainage is needed.

It is doubtful whether the determination of depth and spacing by formulae will become an exact procedure in the near future, because of the heterogeneity of soils, climatic differences, and changes in economic conditions. However, an understanding of the basic principles involved and more detailed information on the physical characteristics of soils can be helpful to drainage engineers in making logical and reliable recommendations.

ACKNOWLEDGEMENT

The authors wish to thank H. D. Ayers, Department of Agricultural Engineering, Ontario Agricultural College, Guelph, for helpful criticism of the manuscript.

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THE EFFECT OF CROP COVER ON THE INFILTRATION CHARACTERISTICS OF GUELPH LOAM SOIL¹

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[Received for publication February 13, 1957]

ABSTRACT

Application of simulated rainfall to a Guelph loam soil indicated that a dense cover crop of grasses and legumes served to maintain the infiltration capacity above 1.6 inches per hour during the first 60 minutes of wet runs. When the cover was removed and the soil surface prepared to simulate a finely prepared seedbed the infiltration capacity dropped to 0.7 inches per hour or less after 60 minutes. The mass infiltration of water during the initial runs on plots appeared to be inhibited by air entrapment in the soil profile.

INTRODUCTION

Infiltration has been defined by Horton (6) as the passage of water through the soil surface into the soil. It is distinguished from percolation, which is the vertical movement of water through the soil profile. The infiltration capacity, f_c , has been defined by Horton (6) as the maximum rate at which a given soil in a given condition can absorb water. If water is applied to a soil at a rate lower than the infiltration capacity it will all enter the environment of the soil at an infiltration rate, f , equal to the application rate.

The infiltration characteristics of a soil are significant from many aspects of water management and utilization. The excess of precipitation or snow-melt over infiltration is manifest as depression storage or surface run-off. When the infiltration capacity of a soil is much lower than the precipitation rate, high rates of surface run-off occur, which may result in flooding and severe erosion of crop land. Design of hydraulic structures for control of surface run-off water is dependent upon a knowledge of watershed characteristics affecting rates and volumes of run-off. The infiltration properties of the soil are important among these watershed characteristics. Design of sprinkler irrigation systems for the efficient application of water can be made only if the rate of application does not exceed the infiltration capacity of the soil. The satisfactory disposal of liquid wastes from canneries by the use of irrigation sprinklers is contingent upon the selection of a disposal area with good infiltration characteristics. Natural or artificial methods of ground water recharge are most successful where the infiltration capacity of the soil is high.

The infiltration tests reported in this paper were for the purpose of evaluating more accurately certain factors affecting infiltration, in addition to obtaining basic data for use in correlating infiltration characteristics of Guelph loam soil with measured run-off hydrographs from a watershed of the same soil type. The determinations were made of field plots during the summer of 1954.

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LITERATURE REVIEW

Several workers have studied the effect of crop cover or residue on the infiltration characteristics of particular soils. Duley and Kelly (4) in Nebraska found that an eroded Marshall silt loam on a 4 per cent slope had an infiltration capacity after 90 minutes of 1.34 inches per hour (in./hr.) with an alfalfa cover, 0.82 in./hr. with a crop of oats, and only 0.30 in./hr. for a bare cultivated soil. Duley (2) further reported that infiltration tests on several soils using a 3-inch covering of straw indicated that removal of this protective covering resulted in a reduction of the infiltration capacity of 1 in./hr. for a Marshall silt loam and 0.09 in./hr. for a Pawnee clay loam. Duley attributed the reduction in infiltration capacity to the breakdown of soil aggregates by the mechanical action of rainfall and the rearrangement of soil particles by water flowing over the surface, resulting in a compacted layer at the surface. He further demonstrated that upon removal of this compacted layer and substitution of a burlap covering the infiltration capacity recovered to a value exceeding that originally existing when the soil was protected by straw. After removal of the burlap covering, the infiltration capacity fell to a new low value. Later work by Duley and Domingo (3) indicated that on native meadow and pasture-land the density of cover including live grass and associated litter was more significant than the type of grass or soil. Duley (2) concluded that the thin compact layer which forms on the surface of bare soils during rains has a greater effect on intake of water than has the soil type, slope, moisture content or profile characteristics.

Similar results have been reported by Borst and Woodburn (1), Sharp, Holtan and Musgrave (8) and others.

MATERIALS AND METHODS

Description of Site

The area upon which the tests were performed was on the south slope of a Drumlin typical of those in the Guelph Drumlin Field. Slopes were from 4 per cent to $9\frac{1}{2}$ per cent. The Guelph loam (5) of the site is a Grey-Brown Podzolic soil developed from limestone till with a moderately well drained profile. The surface 6 inches is a dark greyish brown loam of fine granular structure. The A2 layer has a fine platy structure, a friable consistency, and is slightly stony. The B layer (14-24 inches) at this site is a clay loam with a medium nuciform structure and hard consistency.

At the time of the tests in 1954, the area was in the second year of a ladino clover-orchard grass mixture.

Equipment

Infiltration determinations were made utilizing a rainfall simulator, the type F infiltrometer described by Wilm (10) and following the mimeographed instructions (9) of the Office of Research, Soil Conservation Service, United States Department of Agriculture. The plots were 6 feet wide by 12 feet long. The complete apparatus was enclosed in a tent to eliminate the effect of wind on the application of water. The rainfall

applicator consisted of sets of nozzles mounted 24 inches above the ground on both sides of the plot, so that water was projected vertically upward approximately 8 feet. The nozzle system was designed to simulate the water drop size of an intense rainstorm, and applied the water at 2.00 in./hr. Observations on bare plots indicated that puddling and surface sealing closely simulated the effect of intense rains.

The plots were defined by sheet-metal border plates at the upper edge and sides and by a collection trough at the lower end. The surface run-off from the plot was collected in the trough and conducted through a flume to a pit where a bucket was used to collect samples for weighing.

Procedure

Three separate plots were selected in the study site. On each, infiltration runs were made with the grass-legume cover, after which the sod was turned over with a spade and raked smooth to remove all organic residues from the surface to simulate a finely prepared seedbed. For each surface condition, both an initial or dry run and a wet run were made. The purpose of this was to bring the initial soil moisture content to field capacity on all plots at the time of the wet run.

All tests were of a duration of at least one hour or until the infiltration rate became constant. A time-record of water losses from the plot area due to surface run-off was made by continuous collection of samples which were weighed. A run-off hydrograph was plotted for each trial from which the procedure outlined by Horton (7) was used to plot the infiltration curves.

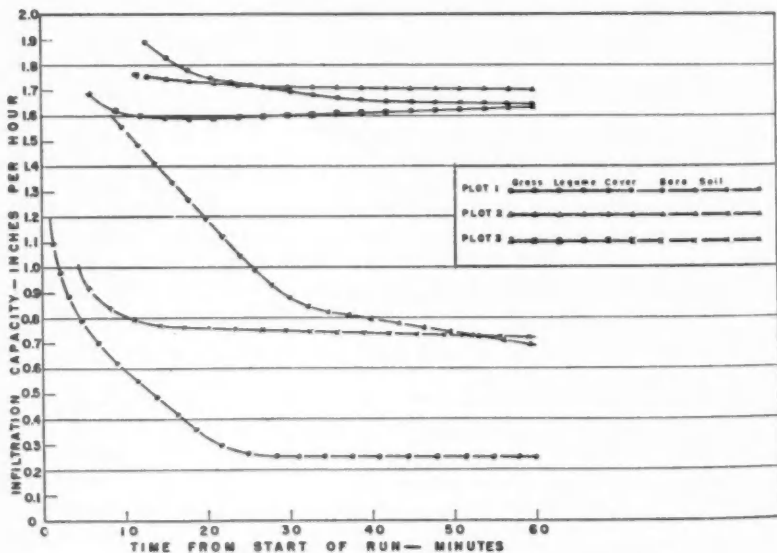


FIGURE 1. Infiltration capacity curves, Guelph loam soil.

RESULTS AND DISCUSSION

Infiltration curves for the three plots under each surface condition are illustrated in Figure 1. It is noted that after 60 minutes of simulated rainfall the infiltration capacity of the soil protected by a dense cover of vegetation was at least 0.8 in./hr. higher than when the soil was bare. Under conditions of crop cover the curves for the three plots are very similar. The same is not true of the same plots when the cover was removed. Visual observations of the bare plots indicated that there was some crusting of the surface soil following the initial run. This was particularly noticeable on Plot 1, where surface run-off started at 1 minute after water was applied. On Plot 2, run-off started after 6 minutes and on Plot 3, 3 minutes after water was first applied during the wet run. The steeper slope (9½ per cent) and low depression storage evident on Plot 1 apparently resulted in higher water velocities over the plot and more severe mechanical action of the water on the soil. These factors no doubt contributed to a smoother surface and greater compaction of the surface soil on this Plot. The final infiltration capacity was much lower for Plot 1 than on the other two when the soil was bare.

The effect of continued application of water for several hours on Plots 1 and 2 under conditions of good cover is illustrated in Figure 2. The infiltration capacity dropped gradually to 1.3 in./hr. after 4 hours (Plot 2) and 0.9 in./hr. after 6 hours (Plot 1), after infiltrating at a constant rate for a period of about 1 hour. This second decrease in infiltration capacity may be due to the moving front of percolating water confronting a soil layer of lower permeability. This may be a case where infiltration capacity was limited by permeability of a lower horizon rather than by surface conditions, particularly since there was an excellent protective crop cover for the soil in this instance.

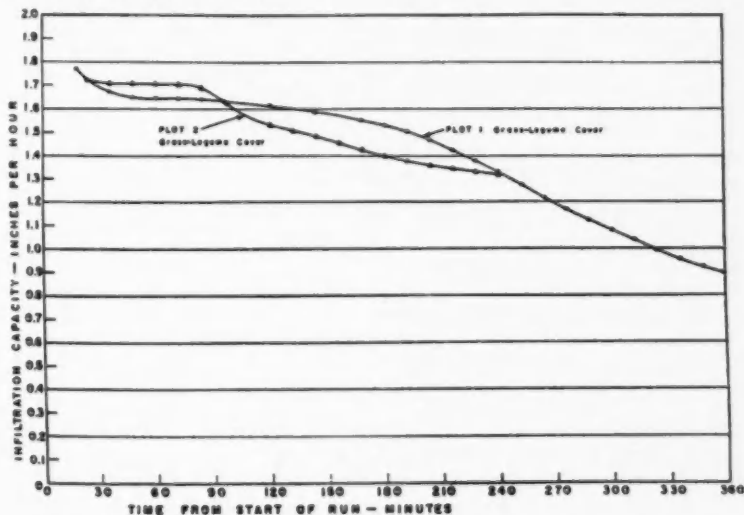


FIGURE 2. Infiltration capacity curves, Guelph loam soil with grass-legume cover.

TABLE 1.—MASS INFILTRATION, (INCHES), INITIAL RUNS

Plot	Time (minutes)						Initial available storage capacity (in.)*
	60	120	180	240	300	360	
1 — cover	1.4	2.5	3.4				6.1
1 — bare	1.2	1.7					
2 — cover	2	3.9	5.6	7.4			5.0
2 — bare	1.9	3.1					
3 — cover	2	4	6	8	9.8	11.7	1.7
3 — bare	1.2	1.8					

* Calculated from soil moisture content at start of Initial Run, bulk density of core samples and specific gravity of the soil, for a 2-foot depth.

TABLE 2.—MASS INFILTRATION, (INCHES), WET RUNS

Plot	Time (minutes)					
	60	120	180	240	300	360
1 — cover	1.7	3.4	4.9	6.4	7.6	8.5
1 — bare	0.4					
2 — cover	1.8	3.4	4.8	6.2		
2 — bare	1.1					
3 — cover	1.6					
3 — bare						

The mass infiltration for initial and wet runs is tabulated for each trial in Tables 1 and 2. It will be noted that there is a greater variation between the mass infiltration of plots under cover at specified times during the initial run than during the wet run. The variation is inverse to the available water storage capacity in the top 2 feet of soil; that is, the mass infiltration is less as the available storage capacity is increased. The impediment to water movement particularly in Plot 1 may be attributed to the greater air entrapment in the soil profile.

In all cases, however, where a good crop cover existed the mass infiltration was greater than any recorded rainfall in the region for the durations listed. Although rainfall intensities in excess of 5 inches per hour have been recorded these have been for very short durations (10 minutes or less). Surface run-off could result from such storms on the Guelph loam soil even though protected by grass-legume cover. However, the duration would be so short that flooding due to run-off concentration is extremely unlikely except on watersheds of a few acres in size.

Even when the soil is bare the infiltration capacity is relatively high. However, the possibility of surface run-off due to intense summer season rainfall is much greater and indeed has been recorded from small watersheds of this soil type when the soil had little or no protective covering of vegetation or litter.

CONCLUSIONS

The infiltration capacity of Guelph loam soil when protected by a grass-legume cover was in excess of 1.6 inches per hour during the first hour of wet runs, and less than approximately 0.8 inches per hour after 60 minutes of water application to the bare soil. Under both conditions the infiltration capacity of this soil is relatively high and should provide no serious problems relative to water control under good soil and crop management practices.

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EVALUATION AND CALIBRATION OF PHOSPHORUS SOIL TEST METHODS FOR PREDICTING FERTILIZER REQUIREMENTS OF POTATOES¹

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[Received for publication May 27, 1957]

ABSTRACT

According to concepts and techniques developed by Bray, ten extracting procedures for soil phosphorus were compared and evaluated against phosphorus response collected from field potato trials conducted in various potato-growing areas of Southern Ontario over three years.

A modification of the PA_2 test, developed by Bray and his associates for the extraction of adsorbed + acid-soluble phosphorus, was chosen as most nearly fulfilling the requirements of a successful soil test under the conditions of this experiment.

The soil test was calibrated against response to phosphorus fertilizer rates resulting in a phosphorus requirement table for potatoes.

INTRODUCTION

The improvement of fertilizer recommendations in Ontario depends primarily on the continued evaluation of soil test methods and the calibration of the results against yield response of crops in the field.

Many methods of measuring available soil phosphorus have been proposed. These involve extraction of the soil with such widely varying extractants as inorganic acids, organic acids, pure or carbonated water, dilute alkali solutions, and buffered salt solutions. Bray and his associates (3, 5, 6, 8, 9) have developed extracting solutions that include the fluoride ion for replacement of adsorbed phosphorus from the anion exchange complex of the soil. Bray and Dickman (8) have shown both the adsorbed and acid-soluble forms of soil phosphorus to be important in crop nutrition. Ketcheson and Bray (11), working with Ontario soils, reported results which suggested the need for considering adsorbed forms of phosphorus along with those at present measured (acid-soluble) in order to improve soil test correlations with crop response.

The objectives of this study were:

1. To evaluate several phosphorus soil test methods in terms of correlation between test results and measured yield response of potatoes to phosphorus fertilizer, and to select the best method.
2. To calibrate the soil test values obtained by this method in terms of fertilizer required for specified yields of potatoes.

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Relationship Between Soil Test and Crop Yield Response

Mitscherlich's Law of Diminishing Returns and Baule's percentage yield concept have been applied by Bray and his associates (5, 7) to the correlation and calibration of soil tests. Bray's modification of the Mitscherlich equation is:

$$\text{Log } (100 - y) = \text{Log } 100 - c_1 b \quad (1)$$

where the yield on the fully fertilized plot = 100%, y = the percentage yield on the adjacent plot from which one fertilizer nutrient (e.g. phosphorus) has been omitted, b = the amount of nutrient (e.g. phosphorus) in the surface soil as measured by soil test, and c_1 = a proportionality constant representing the efficiency per unit of the soil nutrient measured by the test.

The calibration of soil test values in terms of fertilizer requirement involves according to Bray (5, 7) the addition of another term, cx , to Equation (1), as follows:

$$\text{Log } (100 - y) = \text{Log } 100 - (c_1 b + cx) \quad (2)$$

where x is the increment of fertilizer nutrient added, c is a second proportionality constant expressing the efficiency per unit of the added fertilizer nutrient, and y is the percentage yield obtained with any combination of b plus x .

Arnold and Schmidt (4), Arnold (2), and Heeney *et al.* (10) have used these modified equations to show satisfactory correlation between soil tests which measure adsorbed + acid-soluble forms of phosphorus and percentage response of tomatoes to added phosphorus.

TABLE 1.—YEAR, LOCATION, SOIL TYPE, PHOSPHORUS RATING AND pH OF 12 ONTARIO SOILS USED IN STUDY

Year	Area	Soil type	Mod. PA_2 soil test		pH
			lb./ac. P_2O_5	Rating	
1954	Alliston	Brighton f.s.l.	314	Low +	6.2
1954	Alliston	Tioga s.l.	489	Med.	6.1
1954	Shelburne	Honeywood si.l.	601	Med. +	7.0
1954	Shelburne	Honeywood si.l.	237	Low	6.4
1955	Hespeler	Fox l.s.	215	Low	6.8
1955	Belwood	Guelph s.l.	396	Med. —	6.2
1955	Shelburne	Honeywood si.l.	447	Med. —	6.7
1955	Alliston	Brighton s.l.	449	Med. —	6.2
1956	Hillsburg	Brookton s.l.	128	Low —	6.4
1956	Alliston	Tioga s.l.	323	Low +	6.0
1956	Shelburne	Honeywood si.l.	423	Med. —	7.2
1956	Hillsburgh	Fox s.l.	496	Med.	6.2

TABLE 2.—CHEMICAL METHODS USED TO ESTIMATE AVAILABLE SOIL PHOSPHORUS

Method	Extracting solution	Soil: extr. sol'n ratio	Shaking time
Mod. Thornton	0.05N HCl	1:4	1 min.
PSo	0.05N H ₂ SO ₄ + 0.1N NH ₄ Ac	1:10	15 min.
Mod. PA ₁	0.05N NH ₄ F + 0.025N HCl	1:10	1 min.
Mod. PA ₂	0.05N NH ₄ F + 0.1N HCl	1:10	1 min.
PK ₁	0.05N NH ₄ F + 0.005N HCl	1:10 & 1:50	1 min.
*PK ₂	0.05N HCl followed by 0.05N NH ₄ F	1:10 & 1:50	1 min. + 1 min.
Acid-soluble	By difference (PK ₂ —PK ₁)	1:10 & 1:50	

* In the PK₂ method the soil was first shaken for 1 minute with 0.05N HCl, then NH₄F was added to 0.05N and shaking continued for another minute.

MATERIALS AND METHODS

Field Methods

Yield data were obtained from field fertilizer trials conducted during 1954, 1955, and 1956 on several soil types varying in soil phosphorus levels and representing some of the potato-growing areas of the province. Information regarding these soils is presented in Table 1.

The field plots were designed to provide comparisons between plots receiving no phosphorus fertilizer, or increasing increments of phosphorus fertilizer, and those receiving a full phosphorus treatment, for calculation of percentage yields (*y*) required in Equations (1) and (2). Nitrogen at rates up to 100 lb. of N per acre and potassium at rates up to 200 lb. of K₂O per acre were applied to all plots. On the basis of previous experimental data these amounts were considered adequate for maximum yields.

Planting was done by a manual-feed potato planter equipped with an endless-belt fertilizer distributor that applied the fertilizer in bands 2 inches to each side and 1 inch below the seed-piece. Ammonium nitrate, superphosphate, and muriate of potash were used as sources of nutrients.

Laboratory Methods

Soil samples were taken at planting time from each plot that received no phosphorus fertilizer. The samples were air-dried and analysed for phosphorus by the chemical methods shown in Table 2.

The modified Thornton method, developed and calibrated by means of the Neubauer technique by Ruhnke *et al.* (12), employs an extracting solution which removes the easily acid-soluble fraction of soil phosphorus.

The PSo method was devised in this laboratory in an attempt to develop a solution suitable for the simultaneous extraction of available phosphorus and exchangeable potassium. The solution has a pH of approximately 4.8 and extracts essentially the easily acid-soluble form of soil phosphorus.

Bray's original P₁ and P₂ methods for extracting adsorbed phosphorus and adsorbed + acid-soluble phosphorus respectively have been described

by Bray and Kurtz (9). Arnold and Kurtz (3) adapted these methods for photometer use with slight modifications. Arnold (1) referred to these modifications of Bray's original methods as the PA_1 and PA_2 tests. In the present investigation the latter tests were further modified by increasing the fluoride concentration from 0.03N to 0.05N and the shaking time from 40 seconds to 1 minute, and are referred to as the modified PA_1 and modified PA_2 methods. The increase in fluoride concentration and shaking time should effect a more complete extraction of the available phosphorus fractions involved.

The modified PA_1 solution at a pH of 3.5 undoubtedly extracts appreciable quantities of acid-soluble as well as adsorbed phosphorus from most Ontario soils. In an attempt to extract adsorbed phosphorus only from these soils the PK_1 method was devised in which the acid concentration was reduced from 0.025N HCl to 0.005N HCl.

The PK_2 procedure was developed to extract the acid-soluble forms of available soil phosphorus in addition to the adsorbed forms extracted by the PK_1 method. The acid-soluble fraction was then calculated by difference ($PK_2 - PK_1$), thus eliminating any adsorbed fractions which might be included in a single acid-soluble extraction.

Phosphorus in the extracts was determined by a phospho-molybdate blue procedure. For all extracts containing fluoride the ammonium molybdate reagent was saturated with boric acid to overcome fluoride interference with colour development. Stannous chloride was used as the reducing agent in the modified Thornton, PSo, and PK_1 methods, while amino-naphthol-sulfonic acid was used in all other methods to permit the determination of a wider range of phosphorus values.

Extracting solutions containing fluoride were stored in polyethylene containers as it was found that their extracting power decreased rapidly when stored in glass containers. All extractions were made at a solution temperature of $25^\circ\text{C.} \pm 1^\circ$.

TABLE 3.—CALCULATED MEAN C_1 -VALUES FOR POTATOES OVER THREE SEASONS USING VARIOUS EXTRACTION METHODS FOR SOIL PHOSPHORUS

Soil test method	Mean annual c_1 -values			3-year mean c_1	Standard deviation
	1954	1955	1956		
Mod. Thornton	0.01284	0.07000	0.03528	0.04451	± 0.04751
PSo	0.01803	0.03882	0.03169	0.03219	± 0.01894
Mod. PA_1	0.00178	0.00279	0.00204	0.00247	± 0.00084
Mod. PA_2	0.00109	0.00182	0.00152	0.00156	± 0.00055
PK_1 (1:10)	0.00632	0.01054	0.01183	0.01051	± 0.00501
PK_1 (1:50)	0.00217	0.00341	0.00259	0.00283	± 0.00107
PK_2 (1:10)	0.00105	0.00172	0.00141	0.00132	± 0.00054
PK_2 (1:50)	0.00061	0.00121	0.00073	0.00088	± 0.00044
Acid-Sol. (1:10)	0.00129	0.00212	0.00163	0.00176	± 0.00067
Acid-Sol. (1:50)	0.00086	0.00194	0.00102	0.00134	± 0.00079

RESULTS AND DISCUSSION

Evaluation of Methods of Extracting Available Phosphorus

A prime requirement of a successful soil test is that the results show a high degree of correlation with measured crop response in the field. A total of 52 comparisons were obtained in which the yields on plots receiving no phosphorus fertilizer (NK-plots) were less than 98 per cent of the yields on the adjacent fully treated NPK-plots. These percentage yield measurements and the corresponding phosphorus soil test values permitted calculation of c_1 -values according to Equation (1). The mean c_1 -value for all comparisons in each year and the mean c_1 -value for all comparisons over the three years for each soil test method are shown in Table 3.

The standard deviation of each 3-year mean c_1 -value, also shown in Table 3, is a measure of the variability among the 52 individual c_1 -values from which the mean was calculated. Part of the variability was due to weather variation during the three years. In 1955 a severe drought occurred from early spring until August. This resulted in low fertilizer efficiency which in turn placed a relatively high value on the efficiency of the soil phosphorus as reflected in the high c_1 -values obtained in 1955. In 1956 the weather was cool and moist, ideal for potatoes. The 3-year mean c_1 -value was similar to the mean c_1 -value for 1956. Variations in c_1 -values also occurred between different soil types and, in some cases, between different comparisons or replications in the same field, as indicated for two soils and two soil test methods in Table 4. The c_1 -values calculated for the modified Thornton method were more variable than those for the modified PA_2 method both within one soil type or field and between different soil types. Apparently the modified Thornton method failed to extract a proportionate amount of the available phosphorus from each soil sample.

TABLE 4.—VARIATION IN c_1 -VALUES WITHIN TWO FIELDS AND BETWEEN TWO SOIL TYPES FOR TWO SOIL-TEST METHODS

Soil type	Rep.	Per cent yield (y)	Mod. Thorn. method		Mod. PA_2 method	
			Soil test	c_1	Soil test	c_1
Honeywood silt loam (1956)	1	67.7	15	0.03272	350	0.00140
	2	68.5	10	0.05017	364	0.00138
	3	75.6	18	0.03403	435	0.00141
Mean		70.6	14	0.03897	383	0.00140
Tioga sandy loam (1956)	1	91.0	35	0.02988	552	0.00189
	2	72.9	40	0.01418	462	0.00123
	3	79.6	35	0.01973	544	0.00127
Mean		81.2	37	0.02126	519	0.00146

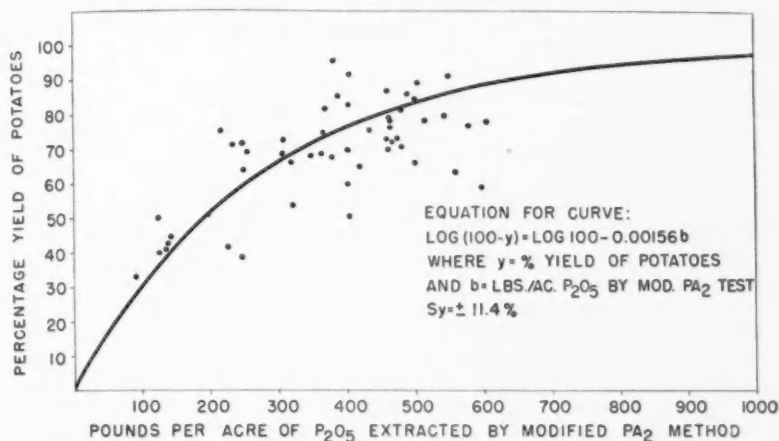


FIGURE 1. Relationship between modified PA_2 soil test values and percentage yield of potatoes.

The coefficients of correlation between the soil test value, b , and the logarithm of the decrement by which a given yield failed to attain the maximum yield, $\text{Log } (100-y)$, are shown in Table 5. Using the calculated mean c_1 -values a curve of best fit relating percentage yield and soil test value was drawn for each method. The curve for the modified PA_2 method is shown in Figure 1. The dispersion of the experimental points about the line of best fit is measured by the standard error of estimate (S_y), also shown in Table 5. The coefficient of variation (V) in Table 5 expresses the standard deviation of the mean c_1 -value as a percentage of the mean c_1 -value.

It is evident from the statistical tests in Table 5 that the modified PA_1 , PK_2 (1:10), modified PA_2 , and acid-soluble (1:10) methods were most satisfactory. Two of these methods, the PK_2 (1:10) and acid-soluble

TABLE 5.—STATISTICAL MEASUREMENTS OF DEGREE OF CORRELATION BETWEEN SOIL-TEST VALUES FOR AVAILABLE PHOSPHORUS AND RESPONSE OF POTATOES TO ADDED PHOSPHORUS

Soil test method	Coefficient of correlation (r)*	Standard error of estimate (S_y)	Coefficient of variation (V)
Mod. PA_1	-0.58	± 11.2	34.0
PK_2 (1:10)	-0.57	± 11.0	40.9
Mod. PA_2	-0.55	± 11.4	35.3
Acid-Sol. (1:10)	-0.53	± 11.3	38.1
PK_1 (1:50)	-0.51	± 12.1	37.8
PK_1 (1:10)	-0.48	± 16.3	47.7
PK_2 (1:50)	-0.41	± 14.0	50.0
Acid-Sol. (1:50)	-0.39	± 15.9	58.9
PSO	-0.39	± 16.6	58.8
Mod. Thornton	-0.34	± 25.7	106.7

* Necessary r for significance at 1% point = 0.354.

(1:10), involving a double extraction, are not so adapted to routine testing as the modified PA_1 and PA_2 methods. The modified PA_2 test provides a much wider range of soil test values than does the modified PA_1 method. As shown in Figure 1, the 52 values from the modified PA_2 test are dispersed fairly uniformly along the line of best fit from approximately 100 to 600 lb./ac. of P_2O_5 . When the modified PA_1 results are similarly plotted, there is a tendency for the majority of the points to be concentrated within rather narrow limits from 200 to 350 lb./ac. of P_2O_5 . Moreover, the PA_2 test removes both adsorbed and acid-soluble phosphorus, while the PA_1 test was designed to remove essentially the adsorbed forms. The PSo and modified Thornton methods, which extract essentially easily acid-soluble phosphorus, gave poor correlation with percentage yield of potatoes. Apparently, these methods failed to measure a constant proportion of the available phosphorus in each soil. According to Bray (5) a successful soil test must measure either the total amount or a constant proportion of the available nutrient. The PA_2 test as modified in this laboratory approximates this requirement for Ontario soils.

Using the equation to the curve for the modified PA_2 method as shown on Figure 1, for any soil test value (b), the expected percentage yield (y) of potatoes without phosphorus fertilization may be predicted.

Calibration of Soil Test Values in Terms of Fertilizer Requirement

If it is to be of practical value, a soil test must be so calibrated that it may be interpreted in terms of fertilizer nutrient required for maximum yield or for a desired percentage of the maximum yield. This may be done by relating the percentage yields obtained under varying increments of phosphorus fertilizer to the soil test value (b) and the rate of fertilizer applied (x) according to Equation (2). The constant (c), expressing the efficiency of utilization of the applied phosphorus fertilizer, was calculated for each increment giving an intermediate yield between the zero rate and the optimum rate on each soil type in 1954, 1955, and 1956. The mean annual c -values and the 3 year mean c -value are shown in Table 6.

The c -value also varied with season. Highest efficiency of fertilizer was in 1956, an ideal year for potatoes, while in 1955, a dry season, potatoes gave less response to fertilizer and hence a low c -value. The standard deviations and coefficients of variation of the mean c -values are also shown in Table 6.

TABLE 6.—CALCULATED MEAN C -VALUES FOR POTATOES OVER THREE SEASONS

Year	No. of observations	Mean c -value	Standard deviation	Coeff. of variation
1954	20	0.00815	± 0.00273	33.5%
1955	6	0.00553	± 0.00215	38.9%
1956	10	0.00984	± 0.00256	26.0%
3-year	36	0.00818	± 0.00290	35.5%

Substitution of the mean c_1 -value for the modified PA_2 test and the mean c -value in Equation (2) now provides a mathematical expression of the average relationship between any modified PA_2 soil test value (b) and the phosphorus fertilizer requirement (x) for potatoes for any desired percentage (y) of the maximum yield obtainable, as follows:

$$\text{Log } (100-y) = \text{Log } 100 - (0.00156 b + 0.00818 x) \quad (3).$$

Fertilizer Requirement Table

By means of Equation (3) the expected percentage yield can be calculated for any combination of $b + x$. And, in addition, the approximate rate of phosphorus fertilizer (x) necessary to supplement the soil supply (b) as measured by the modified PA_2 test can be calculated for any desired percentage (y) of the maximum yield. This permits the construction of a fertilizer requirement table for phosphorus to cover the range of values of the soil test being used. An example of such a requirement table is shown in Table 7 with phosphorus fertilizer requirements calculated for both 95 per cent and 98 per cent of the maximum yield. The decision to fertilize for any particular percentage of the maximum yield must be based on economic considerations including the yield possibility, the value of the crop, and the cost of the fertilizer material. According to the Baule percentage yield concept, however, upon which the technique described in this paper is based, the final percentage yield is the *product* of the percentage sufficiencies of any growth factors below full adequacy. Thus, if both phosphorus and potassium fertilization is carried out for 95 per cent yield, according to the requirement tables for each, the resultant yield, other growth factors being adequate, should approximate $.95 \times .95$ or only 90 per cent of the maximum.

TABLE 7.—PHOSPHORUS REQUIREMENT OF POTATOES BASED ON A MODIFIED PA_2 SOIL TEST

Soil test (lb./ac. P_2O_5)	% yield without P	Phosphorus requirement (lb./ac. P_2O_5)	
		For 95% yield	For 98% yield
100	30	140	189
150	42	130	179
200	51	121	170
250	59	111	160
300	66	102	150
350	71	92	141
400	76	83	131
450	80	73	122
500	83	64	112
550	86	54	103
600	88	45	93
650	90	35	84
700	92	26	74
750	93	16	65
800	94	6	55
850	95		46
900	96		36
950	96.5		27
1000	97		17

The fertilizer requirement table presented in Table 7 is, of course, restricted in its use. For instance, it can be used only with the modified PA_2 phosphorus test as herein described, and is valid for potato fertilizer recommendations only. The phosphorus fertilizer applied must be in the form of superphosphate, and banded in a position similar to that used in the field experiments. Results will be more nearly accurate under climatic and soil conditions similar to those under which the correlations were made.

Fertilizer requirement tables should be considered only as useful guides to the interpretation of soil test results. They must be used with a knowledge of the favourableness of other growth factors in crop production, especially nitrogen and moisture supplies. However, when prepared from field data obtained under controlled conditions and over a representative range of soil and seasonal conditions, and used with an experienced and intelligent realization of their scope and limitations, they should increase both the accuracy and the uniformity of fertilizer recommendations.

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NOTE ON THE OCCURRENCE OF AMINO GROUPS IN SOIL ORGANIC MATTER⁽¹⁾

It is known that a large percentage of the nitrogen of soils is in the form of amino acid polymers. It is important to know whether the amino groups at the end of the chain are free or combined, and the nature of their possible combination. Bremner (1) found that the Van Slyke nitrous acid method gave abnormally high results with soil organic matter, but Sowden and Parker (8), Okuda and Hori (6), and Bremner (1) using Sanger's fluorodinitrobenzene method, failed to detect significant amounts of free amino groups in soil materials. Work in this laboratory, using Edman's phenylisothiocyanate method as originally devised (3) and as modified (7), confirmed the results obtained with Sanger's method.

Recently Fraenkel-Conrat (4) further modified Edman's method by using strips of filter paper as carriers of the protein. This distributed the material over a large surface and rendered it more accessible to the reagents. The application of this method to soil materials is reported here.

Two samples of soil humates isolated from different soils by peptization, [first humate group 2a fractions from Lacombe and Lennoxville soils (9)], a sample of decomposed leaf litter and a sample from the lower part of an A₀ horizon of a podzol soil were dispersed in ammonium hydroxide and applied to paper strips. These were dried, saturated with 20 per cent phenylisothiocyanate in dioxane and exposed to vapours of pyridine, dioxane and water in a closed container for three hours at about 40°C. After drying again, the strips were washed thoroughly with benzene and then with pure ether-absolute ethanol (1:1). They were dried and left overnight at 100-mm. pressure in a desiccator containing beakers of glacial acetic acid and 6N hydrochloric acid. When the acid vapours had been carefully removed from the strips, the latter were extracted with ether-ethanol (1:1) to obtain the thiohydantoins formed by reaction between any terminal amino acid with a free amino group and the phenylisothiocyanate. The solvent was evaporated and the residues were dissolved in ethyl acetate; these solutions were washed with water and the ethyl acetate driven off. The residues were dissolved in ethanol and their ultraviolet absorption curves determined. The ethanol was removed and the phenylthiohydantoins were converted to amino acids by hydrolysis with 6N hydrochloric acid in sealed evacuated tubes for 16 hours at 150°C. After the acid was removed, the amino acids were chromatographed with butanol-acetic acid-water (4:1:1).

With the first application of the above procedure, the ultraviolet absorption curves gave no evidence of thiohydantoins and no amino acids were found on the paper chromatograms. This confirmed previous work that detectable amounts of free amino groups do not occur in soil organic matter. When the procedure was repeated on the residual material on the same paper strips, however, the ultraviolet absorption curves indicated the presence of some thiohydantoins and the paper chromatograms showed the presence of several amino acids for each sample. Small amounts of basic amino acids, aspartic acid, serine and/or glycine, threonine and/or glutamic acid were indicated. In the case of the decomposed leaf litter

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and one humate sample, alanine and leucine may have been present. There was little evidence that the amino group of any specific amino acid was freed; rather it suggested that the occurrence of N-terminal amino acids was random.

A third application of the procedure to these strips gave results similar to the second. Since peptide bonds are not broken by this method, it is tentatively suggested that the first treatment of the organic matter with acid vapours removed metals that were blocking the amino groups; thus the latter were free to react during the second application of the modified Edman procedure. Bremner *et al.* (2) and Martin and Reeve (5) have emphasized the importance of organic matter-metal complexes in soils and isolated humate fractions. Further work along this line is being undertaken.

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May 17, 1957

NOTE ON THE EFFECT OF STUBBLE AND STRAW RESIDUE ON THE AVAILABILITY OF NITROGEN

Experiments conducted at the Experimental Farm, Brandon, Manitoba, in 1955 and 1956 were designed to estimate the quantity of fertilizer nitrogen required to overcome the depressing effect of cereal crop residues on the nitrogen available for crops growing on soil containing these residues.

Table 1, Part A, presents a summary of the average yield of oats obtained from three tests, each of which compared three rates of nitrogen factorially combined with four rates of straw on two soil associations, Assiniboine clay loam and Souris sandy loam. In 1955, the experiment was confined to the well drained associate of Souris sandy loam. In 1956 the experiment was extended to include both soil associations with two replicates located on each of three well defined associates within the two associations. A suitable plan for this arrangement was provided by replicating each experiment six times. Plots consisted of 6 rod-rows, spaced 9 inches apart.

Table 1, Part B, contains the results obtained on the poorly drained clay associate.

TABLE 1.—EFFECT OF INCREASING RATES OF CEREAL STRAW AND NITROGEN ON YIELD OF OATS, AND ON THE QUANTITY OF NITRATE-NITROGEN RELEASED DURING 3 WEEKS OF INCUBATION.

Treatment		Stubble alone 500 lb./ac. of straw	Stubble +1500 lb./ac. straw	Stubble +3000 lb./ac. straw	Stubble +4500 lb./ac. straw
P ₂ O ₅ as 11-48-0	Nitrogen as 33.5-0-0				
lb./acre	lb./acre	Part A—Mean yield of oats bu./ac. (18 replicates)			
20	0	61.1	62.2	53.7	64.1
20	30	86.3	82.8	84.0	87.2
20	60	99.8	101.2	100.8	105.3
	Mean	82.4	82.1	79.5	85.5
		Part B—Mean yield of oats (poorly drained, 2 replicates)			
0	0	42.9	39.9	34.1	34.1
20	0	44.4	41.2	33.7	39.0
20	30	64.9	59.6	59.4	65.0
20	60	98.8	82.3	81.4	80.4
	Mean	62.8	55.8	52.2	54.6
		Part C—Mean nitrogen released—p.p.m. N (3 weeks' incubation)			
		18.5	9.3	4.2	1.7
		Part D—Poorly drained—p.p.m. N (3 weeks' incubation)			
		26.6	16.8	0.9	4.4

Table 1, Part C, shows the effect of increasing rates of straw on nitrate release as determined by incubation tests. For this purpose soil samples were collected from each experiment, and the results as shown are a mean of the six soils tested.

Table 1, Part D, is similar to *Part C*, except that the data came from the poorly drained Assiniboine associate only.

The poorly drained clay associate was the only one in which increasing rates of straw application affected the yield of oats. It should also be noted that this associate contained the greatest amount of available nitrogen, according to incubation tests.

Results obtained under the conditions of this experiment show that cereal crop residues were not as important in influencing the availability of nitrogen as might be anticipated from reading other reports on the subject.

— W. S. FERGUSON,
Field Husbandry Division,
Experimental Farms Service,
Canada Department of Agriculture,
Brandon, Manitoba.

April 4, 1957

STATEMENT OF EDITORIAL POLICY AND PRACTICE
for the
CANADIAN JOURNALS OF "ANIMAL", "PLANT", and
"SOIL SCIENCE"

TYPES OF MANUSCRIPTS ACCEPTED

The Agricultural Institute of Canada publishes, in the "*Canadian Journal of Animal Science*", the "*Canadian Journal of Plant Science*", and the "*Canadian Journal of Soil Science*", papers reporting original research on matters relating directly to technical agriculture. Reviews of a general or purely informative nature are not usually accepted, although the Editorial Board reserves the right to invite or accept authoritative reviews from time to time.

The Editors are prepared to accept a limited number of Notes as follows:

(a) *Research Notes*, of such import as to warrant immediate release. It is expected that such Notes will be followed up by more detailed presentations or that results will be included in some subsequent, more extensive publications.

(b) *Technical Notes*, dealing with subjects such as laboratory techniques, field observations and special equipment. Such Notes would be of assistance to the research worker but would not warrant full-length publication. They would not receive the same priority of publication as would research notes.

Papers submitted must not have been published elsewhere or copyrighted. They should be as concise as is compatible with clarity. Literature reviews should be limited to only the most pertinent references. The nature of the study should be clearly stated and its scope should be defined. Results should be presented as tables, or as figures, or in the text. Presentation in more than one of these ways is definitely undesirable.

EDITORIAL BOARD

The three Journals have a common Editorial Board, appointed by the National Council of the Agricultural Institute of Canada, and consisting of (a) eight members, each of whom serves for a 4-year term and two of whom retire each year; and (b) two other members, the Executive Secretary, ex officio, and a representative of the Canada Department of Agriculture. The members are selected so as to represent all fields of agriculture. The Board is responsible for making recommendations to National Council concerning editorial policy and practice for the three scientific Journals.

Representatives of Affiliated Societies are appointed by the National Council, on recommendation of the Society concerned, to assist members of the Editorial Board in the work of reviewing and editing papers submitted for publication. For the "*Canadian Journal of Plant Science*" there are three representatives, one each from the Canadian Society of

Agronomy, the Canadian Phytopathological Society, and the Canadian Society for Horticultural Science. For the "*Canadian Journal of Soil Science*", there are two representatives of the Canadian Society of Soil Science; and for the "*Canadian Journal of Animal Science*", there are two representatives of the Canadian Society of Animal Production.

REVIEWING

The members of the Editorial Board and the Society representatives are responsible for (1) seeing that the manuscripts submitted for publication are properly reviewed; (2) preparing the necessary editorial comments; (3) accepting or rejecting the final submissions, bearing in mind the high standards desired. The present policy of the Board envisages the ultimate establishment of research journals which will have international recognition in their fields. To accomplish this, the standards, not only for quality of work but also for its presentation, must be high.

The Editor receives the manuscript and, in consultation with the Managing Editor, decides on the Editorial Board member or Society representative who is most likely to have some acquaintance with the subject matter of the paper, to whom the paper is then submitted. On its receipt, the person selected will normally have the paper reviewed by two other workers, independently. In those cases, however, where he feels that the subject is within his own area of competence, a review by one other worker may be sufficient. He will use the reviews, together with his own estimate of the paper, to prepare the final editorial comments which will be returned to the Editor for transmission to the author.

The reviewer is directed to assess the extent to which the paper submitted does in fact represent a piece of research carried to a well-defined stage of advance and the extent to which the conclusions are adequately supported by the experimental results. He should aim at inducing the author to condense and systematize his paper whenever necessary and to use judgement in selecting critical or representative results for presentation. He should scrutinize the paper carefully to ensure that the conclusions are sound and that the facts established by the actual investigation are not advanced in support of conclusions other than those which are legitimate. He should encourage authors to keep matters of speculation and expressions of opinion at a minimum, and to present them in short, clear statements. Every reasonable effort should be made to excise redundant, ambiguous or imprecise words, phrases or passages.

EDITORIAL COMMENTS

The aim of the editorial comments is to assist the author and to secure his co-operation in producing a better paper. In their preparation, the Board member or Society representative is responsible for answering the following questions:

- (a) *Does this paper contain sufficient original material to justify publication in a journal devoted to original work?*

(b) *Is this paper either*

1. *inappropriate for the journal and therefore unacceptable?*
2. *acceptable as it stands?*
3. *acceptable subject to minor revision?*
4. *acceptable subject to major revision?*
5. *unacceptable?*

In those cases where the author believes that the editorial comments are not well founded, he has the privilege of asking for another independent review.



